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A TELEVISION RECEIVER SUITABLE FOR FOUR STANDARDS

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621.397.62

Designing a television receiver suitable for four standards — 625 or 819 lines, positive or negative picture modulation, frequency modulation or amplitude modulation of the sound, and differing synchronizing signals — would seem at first sight to be hardly a promising undertaking. Nevertheless, it has been possible to design and produce such a receiver (e.g. type no. 17 TX 100A-70), and thus to meet a need which is felt particularly in Belgium and the adjacent areas.

The fact that various television standards are in use in Europe, faces receiver designers with the problem of constructing sets suitable for more than one standard. This problem is particularly pointed in Belgium, which has two standards of its own (for the Walloon and Flemish broadcasts), both of which differ from the standards in neighbouring countries. In the North and East of Belgium the Dutch and German broadcasts can be received, working on the "Gerber standard" [1]), and in the South good reception is possible from Lille, a transmitter using the French standard. Conversely, in the areas adjoining Belgium, reception of the Belgian stations is possible. A demand has therefore arisen for sets suitable for two, three or even four standards. The principal data concerning these standards are given in *Table I.*

[1]) So called after the chairman of the sub-committee of the C.C.I.R. which established this standard.

In this article some of the problems involved in designing a receiver for four standards will be discussed.

The intermediate frequency amplifiers

The receiver in question (*fig. 1*) is fitted with a knob for selecting the desired standard. The knob operates a number of switches (*fig. 2*) which constitute the standard selector. Wholly independent of this is the usual channel selector, with which the H.F. section of the receiver can be tuned to a number of television channels. This is done by changing coils, which are mounted in a rotating drum for this purpose (*fig. 3*). The channel selector in the four-standard receiver is fitted with components which give a choice of ten channels with the Belgian standards and the Gerber standard and an eleventh channel, viz. that for Lille (or, if desired, for another transmitter, e.g. Saarbrücken or Strasbourg).

The channel selector, of course, changes not only

Table I. Principal data for the television standards in use on the continent of Western-Europe. N = number of lines. f_s = frequency sound carrier. f_v = frequency vision carrier. AM = amplitude modulation. FM = frequency modulation.

Standard	N	Channel width Mc/s	$f_s - f_v$ Mc/s	Picture mod.	Sound mod.	Line pulse duration µs	Frame pulses Number	Frame pulses Duration µs	Equalizing pulses
Belgium, Flemish	625	7	5.5	pos.	AM	5	6	25	present
Belgium, Walloon	819	7	5.5	pos.	AM	5	6	25	present
"Gerber"	625	7	5.5	neg.	FM	5	6	25	present
France	819	13.15	± 11.15	pos.	AM	2.5	1	20	absent

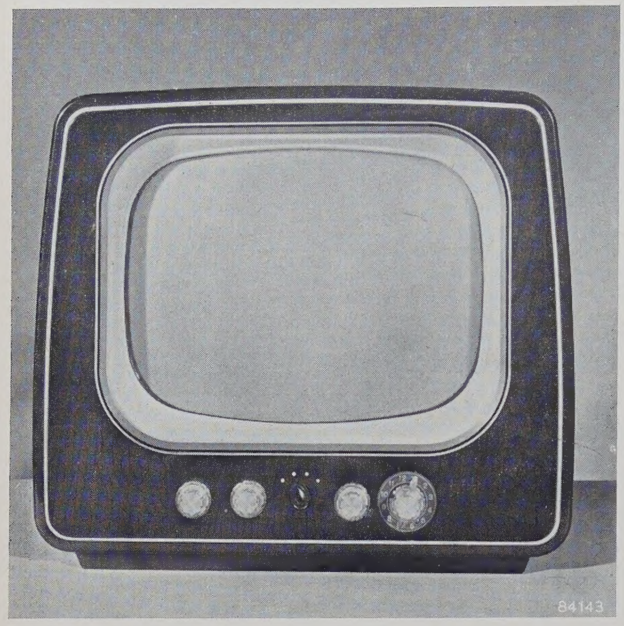


Fig. 1. Television receiver type 17 TX 100A-70 for four standards (the two Belgian, the French and the Gerber standard). In the centre is the standard selector, extreme right the channel selector.

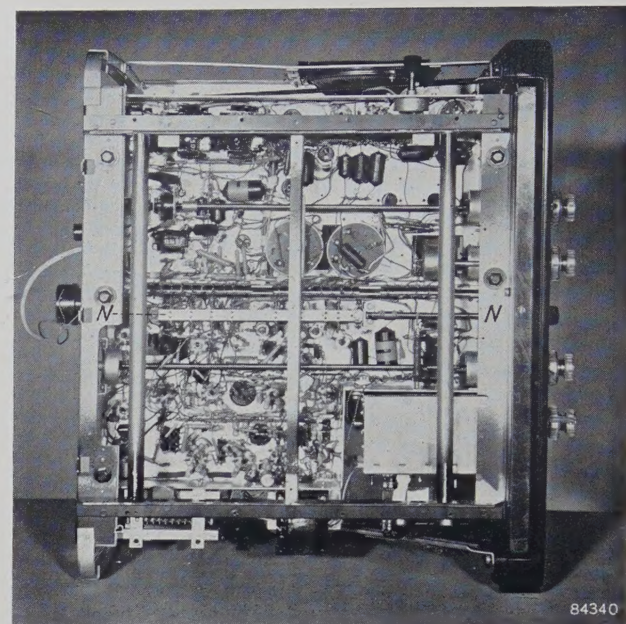


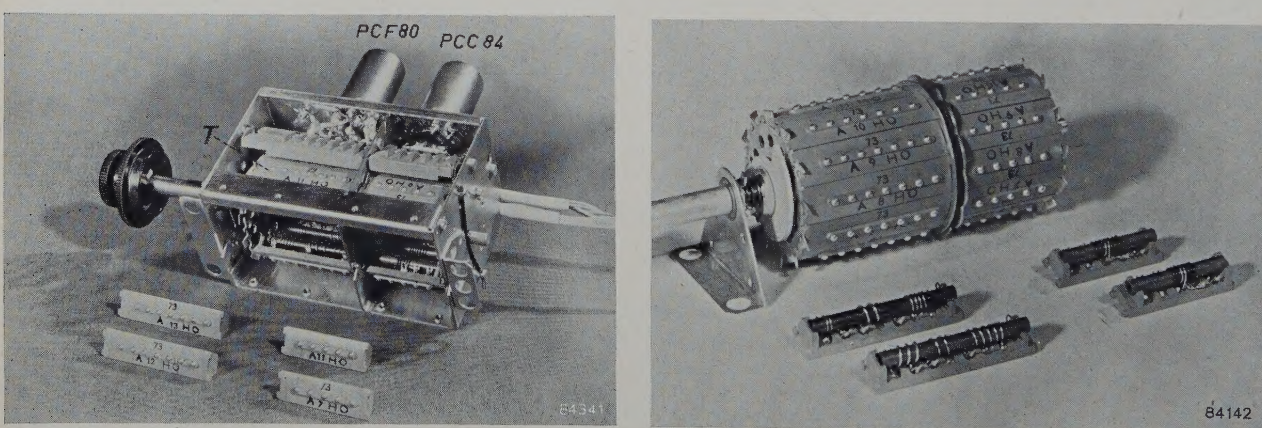
Fig. 2. Chassis of the set illustrated in fig. 1, seen from below. *NN* is the spindle of the standard selector which runs right through the chassis.

the tuning of the receiving circuits, but also that of the local oscillator which, in combination with the received signal, produces the I.F. vision and sound signals.

Picture channel

At first sight it appears to be impracticable to use one vision I.F. amplifier unchanged for the four standards, because the French standard works with about twice the bandwidth of the other three (about 11 Mc/s compared with about 5.5 Mc/s). It is, of course, possible in principle to construct an I.F. amplifier which can be adjusted at will to one bandwidth or the other, but this would make the switching very complicated. Furthermore, it would then be necessary to introduce switches between points with an I.F. potential difference, which would influence the stability unfavourably.

From a large number of observations it has become apparent to us that with a bandwidth limited to about 4 Mc/s, the French picture is acceptable in every respect. Without harming the quality of the image seriously, one vision I.F. amplifier, with a bandwidth of about 4 Mc/s, will therefore suffice



a *b*

Fig. 3. *a*) High frequency stage incorporating channel selector (opened) as used in Philips television receivers. PCC 84 H.F. tube, PCF 80 first oscillator and frequency changer (both in screening cans). *T* rotating drum — shown separately in (*b*) — and the alternative coils. Each set of coils is mounted on an insulated block with contacts. In the foregrounds some of the coils are shown separately; in (*a*) from the contact side, in (*b*) from the coil side.

for all four standards. Thus we have to deal with only one vision I.F.

The question now arises as to how the desired I.F. is to be obtained: should the frequency of the local oscillator be higher or lower than that of the vision carrier? As with the design of ordinary radio sets, the possibility of interference (e.g. between harmonics of the oscillator and harmonics of the desired or another transmitter) is here decisive. For the Belgian standards and the Gerber standard, the chance of interference is least when the oscillator frequency is higher.

For transmitters with these three standards and for about half the French transmitters, the sound carrier frequency is also higher than the vision carrier frequency; for the other French transmitters — including Lille in channel 8a, the very one of importance for Belgium — it is lower (see *Table II*). If the same picture I.F. amplifier is to be used, it is therefore necessary to choose the oscillator frequency lower than the vision carrier frequency in order to receive a French transmitter in the latter group. This occurs automatically with the channel selector: In choosing the channel, the oscillator coil is inserted which gives the correct frequency.

The next question is: for what I.F. must the vision amplifier be designed? From interference considerations, it appears that, for the Belgian and Gerber standards, the most favourable I.F. for the picture is 38.9 Mc/s. For the sound, this amounts to 38.9 — 5.5 = 33.4 Mc/s for these three standards (*fig. 4a*) and to 38.9 — 11.15 = 27.75 Mc/s for the French standard (fig. 4*b*).

A filter in every stage of the vision amplifier (*fig. 5*) ensures suppression of the sound signal, which is attenuated by a factor 500, and of signals from neighbouring channels. The bandwidth of approximately 4 Mc/s is obtained by somewhat staggering the circuits of successive stages. *Fig. 6* shows the selectivity characteristics. That for the French standard shows a slightly greater bandwidth: this is because one of the filters is tuned to 27.75 Mc/s, and not to 33.4, so that in the neighbourhood of 34 - 36 Mc/s the suppression is less and the band therefore wider.

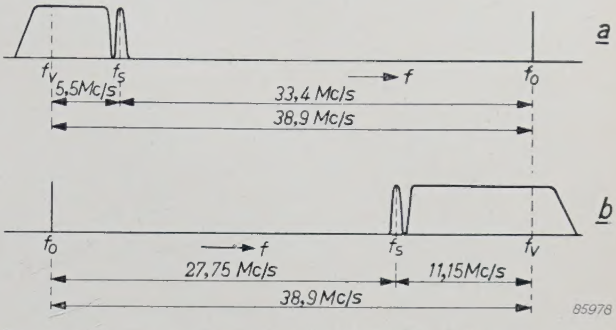


Fig. 4. *a*) Frequency spectrum for one of the Belgian standards and the Gerber standard. The sound carrier frequency f_s is 5.5 Mc/s higher than the vision carrier frequency f_v. A favourable value for the frequency f_o of the local oscillator is f_v + 38.9 Mc/s = f_s + 33.4 Mc/s.
b) The same for a French television transmitter such as Lille. Here $f_v - f_s$ = 11.15 Mc/s. For $f_o = f_v$ − 38.9 Mc/s, $f_s - f_o$ = 27.75 Mc/s.

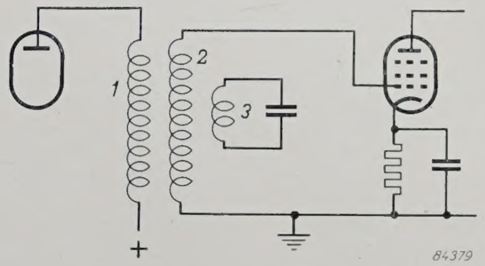


Fig. 5. Coupling between two stages of the vision I.F. amplifier. *1* primary, *2* secondary coil of the coupling transformer. *3* filter tuned to the frequency of an interfering signal.

Table II. Carrier wave frequencies for the Belgian, Dutch, German and French television transmitters. f_v = vision carrier frequency, f_s sound-carrier frequency.

	Gerber standard and Belgian standards			French standard		
Freq. band	Channel	f_v Mc/s	f_s Mc/s	Channel	f_v Mc/s	f_s Mc/s
I (low)	2	48.25	53.75	2	52.40	41.25
	3	55.25	60.75	3	56.15	67.30
	4	62.25	67.75	4	65.55	54.40
III (high)	5	175.25	180.75	5	164.00	175.15
	6	182.25	187.75	6	173.40	162.25
	7	189.25	194.75	7	177.15	188.30
	8	196.25	201.75	8	186.55	175.40
	9	203.25	208.75	8a	185.25	174.10
	10	210.25	215.75	9	190.30	201.45
	11	217.25	222.75	10	199.70	188.25
				11	203.45	214.15
				12	212.85	201.70

Sound channel

We have just seen that in the sound channel we have to deal with two I.F. values, viz. 33.4 and 27.75 Mc/s. In amplifiers for frequencies of this magnitude the amplification per stage is limited by the grid-to-anode capacitance to a very small value. To obtain a considerable amplification, it is therefore necessary to have many stages. One is therefore not anxious to include two I.F. amplifiers for the sound channel in the set. One of these could be eliminated by transforming one I.F. signal to the frequency of the other. This, however, leaves another problem unsolved, viz. the design of a frequency detector (for the Gerber standard) which, at this high I.F.

not only suppresses amplitude variations well, but is also suitable for mass production. (In receivers for the Gerber standard alone, this difficulty is overcome by using the inter-carrier sound system [2])).

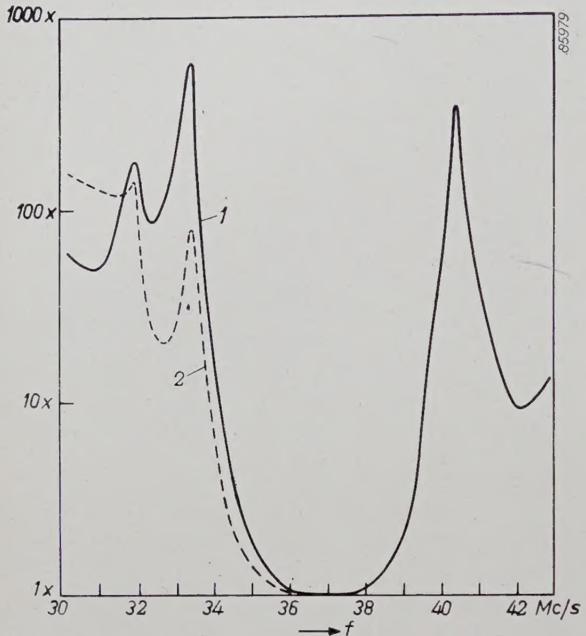


Fig. 6. Selectivity characteristic of the vision I.F. amplifier (MF_1 in fig. 7), *1* for the Belgian standards and the Gerber standard, *2* for the French standard.

Actually there is no reason why we should not use a second frequency transformation to bring both sound intermediate frequencies down to a much lower I.F. This second I.F. must, however, be very carefully chosen because the chance of interference is here very considerable. An analysis has shown that 7 Mc/s is the most suitable second I.F. — a value at which the frequency detector presents no particular problems.

To transform 33.4 Mc/s to 7 Mc/s, one can choose an oscillator frequency of either 33.4 + 7 = 40.4 Mc/s or 33.4 — 7 = 26.4 Mc/s. 40.4 Mc/s happens to be the more favourable. This frequency coincides with the sound carrier frequency of the higher adjacent channel (38.9 + 1.5 Mc/s); filters tuned to this frequency ensure that the amplification is reduced by a factor 200, which is sufficient to prevent interference. Of the harmonics, only the fifth, with the frequency 5 × 40.4 = 202 Mc/s, can interfere, but this lies on the sound side of channel 8 (table II) and can thus produce no interference in the picture. It is of importance that the frequency of the second oscillator be very stable, as otherwise multiples of it might assume values that lie in the pass-band of the vision I.F. amplifier.

[2]) See e.g. W. Werner, Philips tech. Rev. **16**, 195-200, 1954/55 (No. 7), in particular pp. 198-199.

To transform the sound I.F. of 27.75 Mc/s, which occurs in reception of a French transmitter, to 7 Mc/s, there is the choice of oscillator frequency between 27.75 + 7 = 34.75 Mc/s and 27.75 — 7 = 20.75 Mc/s. The former does not come into consideration because it falls in the band of the I.F. picture signal (see fig. 4*b*). Nine times the other value (9 × 20.75 = 186.75 Mc/s) differs 1.5 Mc/s from the vision carrier frequency of Lille (185.25 Mc/s, see Table II), but in this case, too, filters in the amplifier suppress adequately.

Table III gives a summary of the chosen I.F. values and second oscillator frequencies.

Table III. Intermediate frequencies and second-oscillator frequencies in the four-standard receiver.

	Belgian standards and Gerber standard	French standard
I.F. picture	38.9 Mc/s	38.9 Mc/s
1st I.F. sound	33.4 Mc/s	27.75 Mc/s
Frequency 2nd oscillator	40.4 Mc/s	20.75 Mc/s
2nd I.F. sound	7 Mc/s	7 Mc/s

The fact that the receiver must be suitable for standards with an AM sound signal makes it necessary, 1) that the sound signal be tapped off immediately after the channel selector, and 2) that the sound signal be strongly suppressed in the vision channel, since the picture signal, which is always amplitude modulated, can easily suffer interference from a sound signal which is similarly modulated. This latter point has been given particular attention.

As regards the first item mentioned above, viz. the choice of the point at which the sound signal is tapped off, it would be preferable to place the second frequency-changer tube immediately after the channel selector; the switching in the sound I.F. section is then reduced as much as possible. An objection to this, however, is that the coupling between the second oscillator and the picture I.F. amplifier would then be so close that in the latter the 40.4 Mc/s signal could not be sufficiently suppressed and that an interference of 40.4 — 38.9 = 1.5 Mc/s would remain visible. This difficulty is overcome by inserting an amplifier tube (MF_2, *fig.* 7) between the channel selector and the second frequency-changer tube, so that the coupling is considerably weakened. This extra tube must amplify signals of either of the sound intermediate frequencies (33.4 and 27.75 Mc/s). Switches operated by the standard selector tune the grid and anode circuits to one of these frequencies.

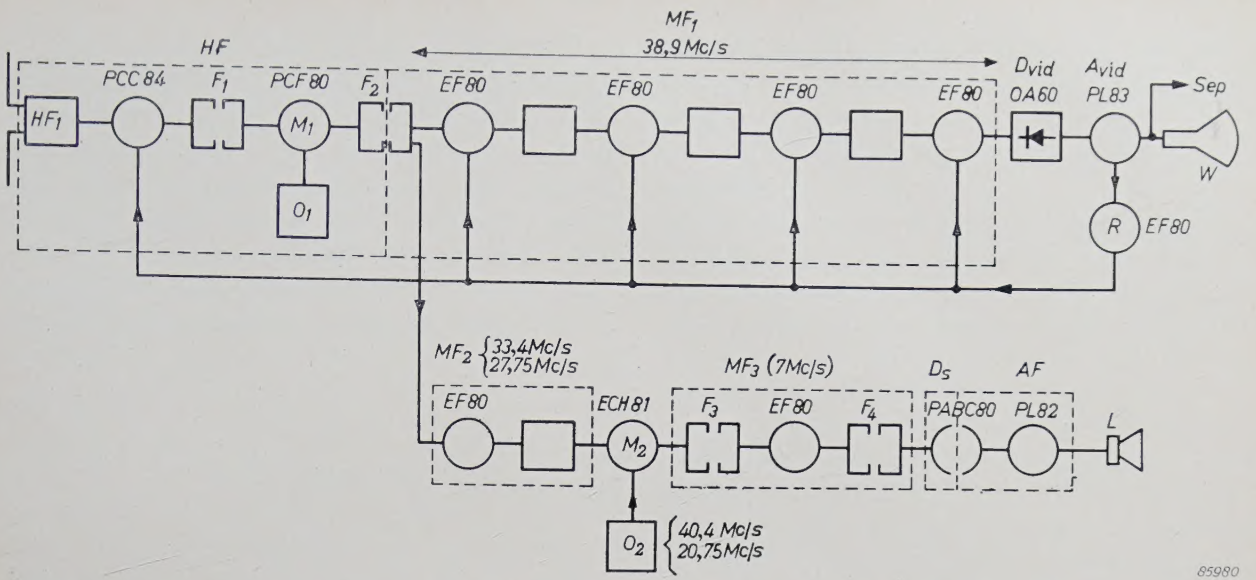


Fig. 7. Block diagram of the television receiver for four standards. *HF* high frequency section (incorporating the channel selector, see fig. 3), with high frequency stage HF_1, high frequency band filter F_1, first oscillator O_1, first frequency-changer M_1 and part of the I.F. band filter F_2.
Vision channel: MF_1 intermediate frequency amplifier with four tubes EF 80, $D_{\rm vid}$ video detector, $A_{\rm vid}$ video amplifier, *R* control tube (see further), *W* picture tube, *Sep* separation of the synchronizing signals.
Sound channel: MF_2 first I.F. amplifier, O_2 second local oscillator, M_2 second frequency-changer, MF_3 second I.F. amplifier (with band filters F_3 and F_4), D_s sound detector (with two diodes in the tube PABC 80), *AF* audio frequency amplifier (with the triode in the tube PABC 80 and a PL 82), *L* loudspeaker.

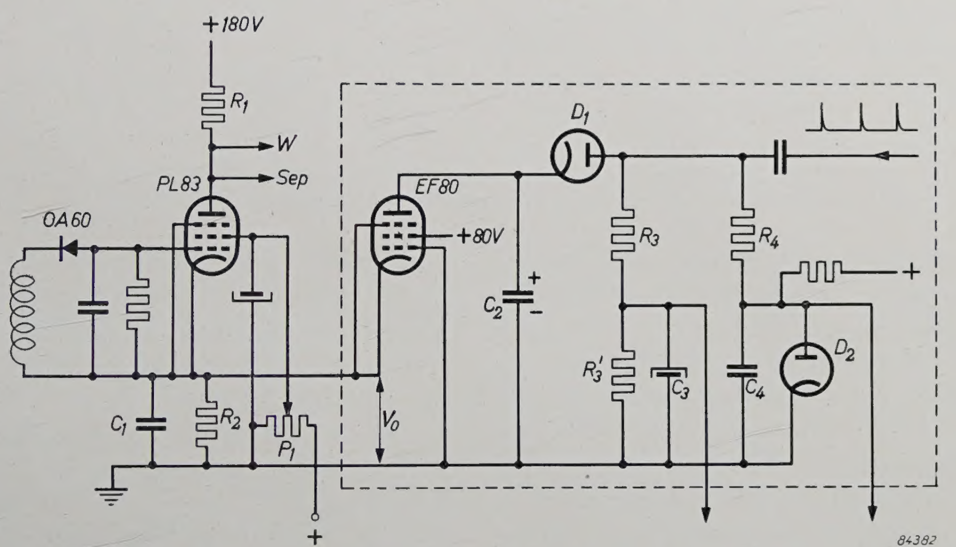


Fig. 8. Diagram of the video stage. Video detector is the germanium diode OA 60, video amplifier the pentode PL 83. The signal at the anode of the PL 83 controls the picture tube (*W*) and the separator (*Sep*), which separates out the synchronizing signals. P_1 contrast control.
Inside the dotted line: automatic gain control of the image channel. The control tube EF 80 receives a control voltage V_0, which appears across the cathode resistor R_2 (for I.F. current, short-circuited by the capacitor C_1) of the PL 83 Pulses originating in the line transformer (horizontal deflection) are rectified by the diode D_1 and supply (across the smoothing capacitor C_2) the anode voltage for the control tube. The control voltage for the I.F. tubes appears across the smoothing capacitor C_3; and the control voltage for the H.F. tube appears across C_4, when D_2 is rendered non-conducting by a strong signal.

To keep the switch-over simple, the coupling elements in the first sound I.F. amplifier are single tuned circuits. The second I.F. amplifier (7 Mc/s), which contains no switches, includes band filters.

The video section and the automatic gain control

The video signal is obtained by detection from the I.F. picture signal. The detector is a germanium diode OA 60 (*fig. 8*). The video signal is applied without bias to the control grid of a video amplifier tube, a pentode PL 83, a type which in this circuit with an anode supply of 180 V, can operate at zero grid voltage, as can occur in the absence of a signal. The tube is fed through an anode resistor; the amplified video signal thus appears with reversed polarity at the anode. This signal controls the picture tube.

According as the picture modulation is negative

(Gerber standard) or positive (the other three standards), the control grid and anode voltages of the video tube vary as shown in *fig. 9a* and *9b* respectively. It will be obvious that in order to avoid a negative picture on the screen, the signal must be inverted at some point in the video section when changing over from one modulation direction to another. In principle this can be done in the video detector, the video amplifier or the picture tube.

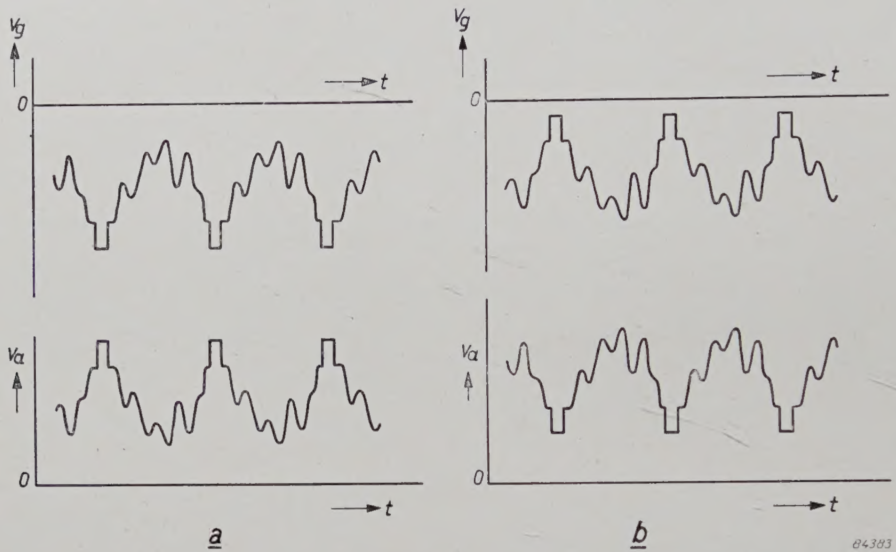


Fig. 9. Control grid voltage v_g and anode voltage v_a of the video tube PL 83 (fig. 8) as a function of time t, *a*) with negative modulation, *b*) with positive modulation.

Reversal at the picture tube has the advantage that no I.F. voltages are present there, and this, then, is the solution chosen. The circuit (*fig. 10*) is so arranged that for positive modulation the video signal is applied to the control grid and for negative modulation to the cathode of the picture tube, while in both cases, the brightness of the picture increases when the knob of the potentiometer P_2, which alters the bias of the picture tube, is turned to the right.

To avoid necessity of hand adjustment, it is desirable that the video signal automatically remains of the same magnitude when switching over from one transmitter to another which supplies a stronger or a weaker input signal. This purpose is served by the automatic gain control which, depending on the video signal strength, supplies the H.F. and I.F. tubes with a larger or smaller bias (control voltage) and so controls the amplification. We must now consider separately the cases of positive and negative modulation.

Negative picture modulation

The video signal on the control grid of the video tube PL 83, as represented in *fig. 11a* and *c*, results in a voltage across the cathode resistor R_2 (see fig. 8); this, in turn, acts upon the cathode of the control tube EF 80, whose grid is earthed. In the absence of a video signal, a large current flows through the video tube, producing across R_2 a direct voltage V_0 which lies far below the cut-off point of the control tube (fig. 11*b* and *d*). Furthermore, the circuit is such that when a video signal of the desired magnitude is present, only the synchronization pulses produce anode current pulses in the control tube. The A.C. component of these pulses passes through the smoothing capacitor C_2, while the D.C. component across the resistors R_3 - R_3' (fig. 8) gives rise to a direct potential across the smoothing capacitor C_3, which can be used as control potential for the I.F. tubes. Interference peaks (*i*, fig. 11*c*), which appear as black spots in the picture and can disturb the synchronization, are clipped by the video tube whenever they exceed the amplitude of the synchronization pulses.

The output voltage of the video tube can be varied simply by adjustment of the screen grid voltage of this tube. This is done by the potentiometer P_1 (fig. 8), which thus regulates the contrast. Adjustment of P_1 alters the cathode voltage V_0 which occurs in the control tube in the absence of a signal, and at the same time the threshold which the signal must exceed before the automatic gain control comes into action.

The H.F. tube PCC 84 (fig. 7) derives its control voltage from the smoothing condenser C_4 in fig. 8. Normally this voltage is zero (and the amplification thus a maximum, which is advantageous from considerations of noise) because the

diode D_2 passes current. Only when the input signal is very strong does there occur via R_4 and C_4 a negative control voltage which makes the diode non-conducting and causes the H.F. amplification to decrease.

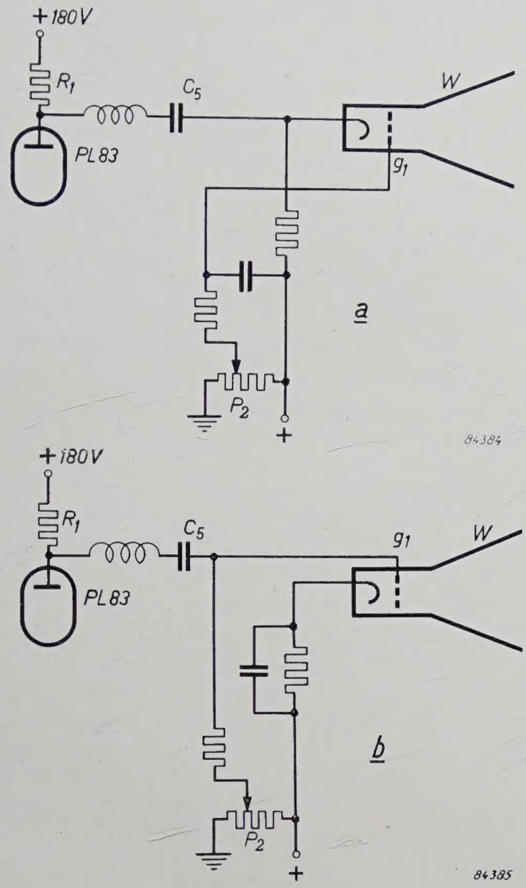


Fig. 10. Control of the picture tube W (with control grid, g_1), a) with negative modulation, b) with positive modulation. A double-pole switch (not shown) makes the change from one to the other. R_1 anode resistor of the video tube PL 83. C_5 coupling condenser. P_2 brightness control.

Positive picture modulation

With negative modulation there is in the peak of the synchronization signal a level which is independent of the picture information: it is thus convenient to use this level as the basis for the automatic gain control, which, as we have just seen, has been done. With positive modulation, however, the only level in the picture signal independent of the picture information is the black level, which is present as a "front porch" and "back porch" at 30% of the maximum white level. Circuits do exist to derive the control voltage from this level, but they are complicated and do not lend themselves well to switching-over into a circuit suitable for negative modulation.

However, we have established that the circuit discussed above can also serve very well for positive modulation. As we have seen, with this circuit the highest peaks of the video signal lie close to the cut-off point of the video tube (fig. 11c). With negative modulation, the peaks are those of the synchronization signal; with positive modulation they are the peaks which correspond to the whitest part of the picture.

This white is not, of course, constant from picture to picture and it may therefore seem strange to base a control system on a variable peak. From a great number of tests, however, it has been shown that, taken over not too short a time, the white level occuring in the various scenes does not vary appreciably. Only in an extreme case of a transmitter sending out a completely black "picture", would this be observed on the screen as white (at least, if the picture tube were fed with the D.C. component of the video signal; in fact this does not happen — see fig. 10 — and the black "picture" would be seen as grey).

The situation with positive modulation is illustrated in fig. 11e (video tube) and 11f (control tube). Interference peaks, which can be particularly tiresome with positive modulation since they appear as very bright, large white spots (see p. 196 of the article referred to in [2])), are clipped whenever they exceed the level of the brightest white in the picture.

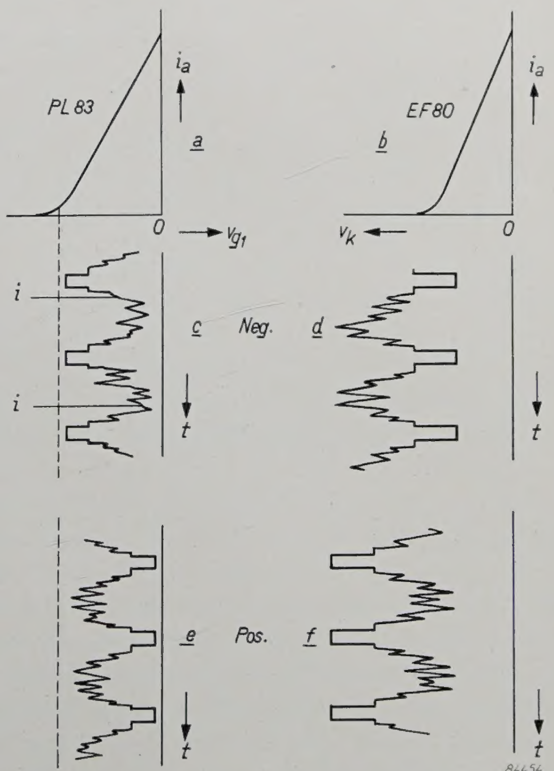


Fig. 11. a) Anode current i_a as a function of the control grid voltage v_{g1}, for the video tube PL 83. b) i_a as function of the cathode voltage v_k (with earthed grid), for the control tube EF 80. c) Control grid voltage of the PL 83, and d) cathode voltage of the EF 80 as a function of the time t, with negative picture-modulation; e) and f) the same for positive picture-modulation.

The sound detector

For the detection of the I.F. sound signal, we have to deal with the fact that of the four standards, three prescribe amplitude modulation (AM) and one frequency modulation (FM). Starting with a conventional FM detector, the so-called ratio detector (*fig. 12a*), and adding to it only a few

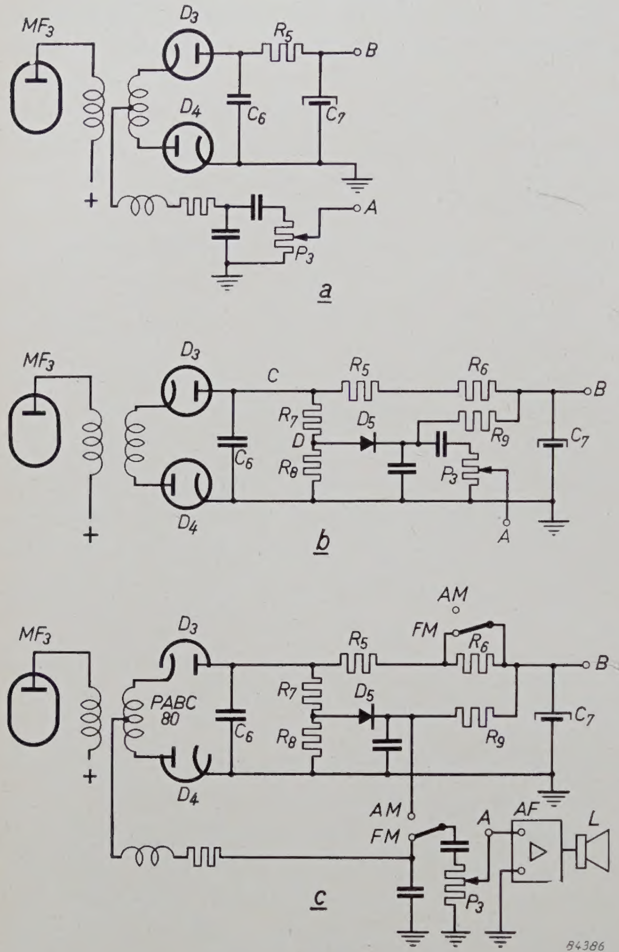


Fig. 12. *a*) Circuit of the ratio detector for FM. *b*) Circuit *a* modified to form an AM detector. *c*) Combination of both circuits, with two single-pole switches FM-AM.
MF_3 intermediate frequency amplifier. D_3 and D_4 are diode sections of a PABC 80, the triode section of which serves as first stage of the A.F. amplifier *AF*. D_5 germanium diode, which acts as interference limiter in the AM detector. P_3 volume control. The control voltage for the automatic gain control is taken off at *B*.

circuit elements and two switches, it has been extended to give AM detection as well. In both cases, besides the audio frequency signal, the detector delivers a direct voltage which is directly related to the amplitude of the I.F. sound signal and which can therefore be used as a control voltage for the I.F. amplifier in the sound channel.

Another well-known FM detector is that of Foster and Seeley [3]), which is preceeded by a limiting device to suppress amplitude variations and interference peaks; the limiting device is usually a pentode with strong input signal [4]). This method is less suitable for television than the ratio detector, however, since the limiter produces harmonics whose frequency may fall in the television channel and cause interference.

The ratio detector itself acts as a limiter, and for strong signals, the preceeding tube as well.

Fig. 12*b* shows the circuit of fig. 12*a*, modified to give AM detection. In both cases the detected signal appears across the capacitor C_6 and the control voltage across the electrolytic capacitor C_7; the potentiometer P_3 is the volume control. At the same time care has been taken that with AM, strong interference peaks are limited. In fig. 12*c* can be seen how the change-over is effected from the one circuit to the other; the two single-pole switches needed for this purpose are included in the standard selector.

The interference limiter of the AM detector works as follows. The anode of a germanium diode D_5 (fig. 12*b*) is connected to the tapping point *D* of the voltage divider R_7-R_8, and the cathode via the resistor R_9 to the point *B*. The detected AM signal appears across R_7 and R_8, i.e. an audio frequency fluctuating direct voltage. The potentials of the points *C* and *D* follow the curves *C* and *D* respectively in *fig. 13*. The direct voltage component of the detected signal occurs across the capacitor C_7 (the straight line *B* in fig. 13). It is seen that in the absence of interference, the point *D* is always positive with respect to the point *B*, so that the diode D_5 always passes current and the A.F. signal really does appear on the potentiometer P_3. Interference peaks such as *i*, however, which make *D* negative with respect to *B*, make the diode momentarily non-conducting and are thus limited to a specified amplitude.

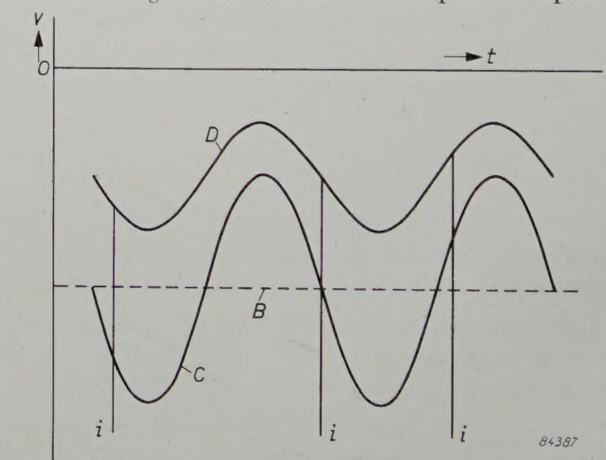


Fig. 13. The straight line *B* and curves *C* and *D* give the voltage variations at the points *B*, *C* and *D* respectively in fig. 12*b* with respect to earth (*O*). Interference pulses are clipped at the level *B*.

The deflection circuits

From the anode of the video tube (PL 83, fig. 8) the signal travels not only to the picture tube, but also to the circuit which separates out the synchroni-

[3]) See e.g. Philips tech. Rev. **8**, 48, 1946, fig. 10, or **11**, 4, 1949/50, fig. 5.

[4]) See e.g. Philips tech. Rev. **11**, 3, 1949/50, fig. 4*a*.

zation pulses. With negative picture modulation the synchronization pulses in the video signal are in the positive direction and the separation can thus be achieved by means of a tube which is so adjusted that the picture signal lies wholly in the cut-off area and only the synchronization pulses produce anode current pulses. With positive picture modulation, the video signal and synchronization pulses are in the negative direction; in this case an inverter tube is inserted between the video tube and the separator tube to reverse the polarity. The inverter stage only requires a small bandwidth, since only the synchronization pulses are of importance here.

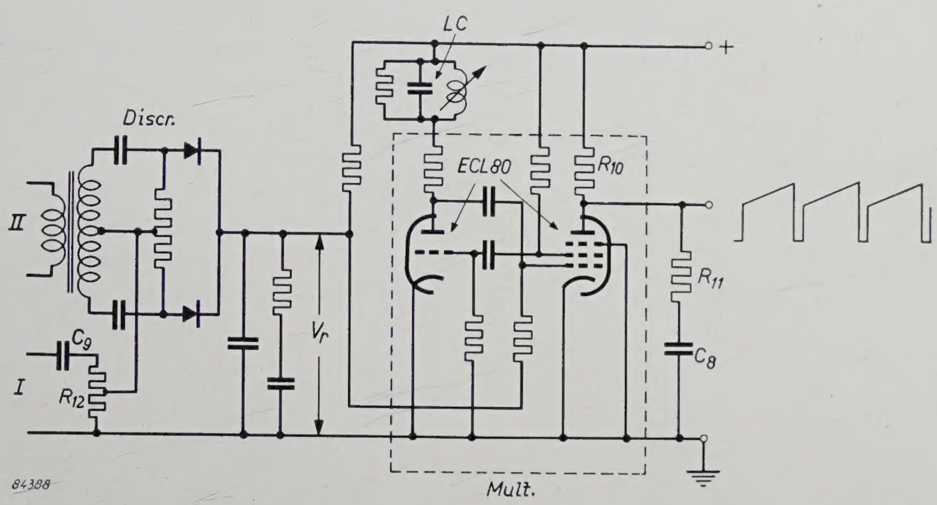


Fig. 14. Generation of the saw-tooth voltage for controlling the final stage for the horizontal deflection. *Mult* multivibrator, whose output voltage (of the form drawn on the right) appears across R_{11} - C_8. *LC* flywheel circuit, *Discr* phase discriminator, producing the control voltage V_r which determines the frequency of the multivibrator. *I* is fed with a voltage of the frequency of the multivibrator, *II* with the synchronizing pulses. C_9 - R_{12} differentiating network.

The frame synchronization pulse is derived in the usual way from the synchronization signal. Despite the fact that the French frame synchronization signal differs from the others (see table I), both forms of signal have proved to give good synchronization and interlacing. The vertical deflection in the four-standard receiver thus presents no further problems and we shall discuss it no further.

The horizontal deflection must be able to work at two line frequencies: 25 × 625 = 15 625 c/s and 25 × 819 = 20 475 c/s. The choice of the type of saw-tooth generator was influenced by the wish to reduce the switching to a minimum. A multivibrator meets this requirement best.

The multivibrator circuit used (*fig. 14*) works with two triodes. One is formed by the triode section of a triode-pentode ECL 80, the other by the cathode, first and second grids of the pentode section of the same tube. The circuit parameters are such that the pentode conducts momentarily at intervals. While the pentode is non-conducting, the capacitor C_8 is charged via the anode resistor R_{10} and a resistor R_{11}. When the pentode conducts, C_8 discharges itself rapidly through this section of the tube and the resistor R_{11} ($< R_{10}$). The voltage across C_8 - R_{11} thus follow the form shown in fig. 14 on the right hand side. This variation is necessary for the control voltage of the final tube in the deflection circuit: the upward sloping section generates a linearly increasing current in the deflection coils and the large negative peak (from — 100 to — 150 V) cuts off the final tube during the retrace, when its anode voltage is very highly positive.

For the horizontal deflection with negative picture modulation, so-called flywheel synchronization [5]) is necessary. With this modulation direction, the interference has the same direction as the synchronization, pulses and thus, with direct synchronization, could cause the saw-tooth generator to change over at the wrong moment. With positive modulation, this danger does not exist, because the interference is in the white direction, but here too, flywheel synchronization is of advantage. When the signal-to-noise ratio is small, the noise, superimposed upon the (not infinitely steep) sides of the synchronization pulse, could give rise to slight phase changes in the change-over of the saw-tooth

[5]) See e.g. P. A. Neeteson, Flywheel synchronization of saw-tooth generators in television receivers, Philips tech. Rev. **13**, 312-322, 1951/52; Television receiver design, Monograph 2: Flywheel synchronization of saw-tooth generators, Philips Technical Library, 1953.

generator, resulting in a "raggedness" of vertical lines. A flywheel system can improve the situation considerably. In the receiver under discussion this system has therefore been used for all four standards.

The flywheel system works, briefly, as follows. By means of a phase discriminator, a control voltage is derived from phase differences between the line saw-tooth (or pulses derived from it) and the line synchronizing pulses. This control voltage is then caused to act upon the saw-tooth generator in such a way that the frequency difference is reduced, even down to zero, owing to the fact that the phase discriminator reacts to the phase difference, which is the time integral of the frequency deviation ("integrating control"). The "flywheel" consists of an LC circuit tuned to the line frequency f_l or an RC combination with a time constant $1/f_l$. This has the effect that interference pulses remain ineffective (except in the very unlikely case that a long series of pulses occurs with the frequency f_l).

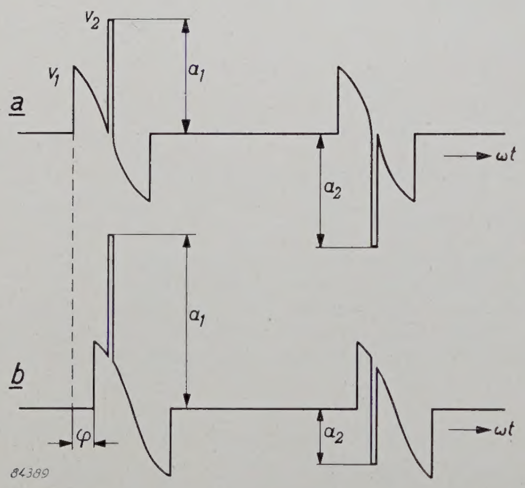


Fig. 15. Production of the control voltage by the phase discriminator. v_1 pulses of the frequency of the multivibrator, v_2 synchronizing pulses. In (a) the phase difference between the two series of pulses is zero; since amplitude a_1 = amplitude a_2, the control voltage is also zero. In (b) a frequency drift of the multivibrator has caused a phase difference of φ between the pulses v_1 and v_2, so that the amplitudes a_1 and a_2 are no longer of equal magnitude. This results in a particular value of the control voltage V_r which is approximately proportional to φ. The control voltage brings the frequency of the multivibrator back to the correct value.

In the four-standard receiver the flywheel is an oscillatory circuit (LC in fig. 14) which, by means of a tapping in the coil, can be tuned at will to either 15 625 c/s or 20 475 c/s (furthermore in the multivibrator one resistor and one capacitor must be changed). The synchronizing knob on the set changes the distance between a copper ring and the coil and so adjusts to synchronization.

The phase discriminator is to be seen at the left in fig. 14. It is fed at I with a voltage of the frequency of the multivibrator (derived from the line transformer), and at II with the synchronizing pulses. A differentiating network transforms the former voltage into a voltage v_1 of the form shown in *fig. 15*. The discriminator comprises two diodes. These are so connected that they deliver together the control voltage V_r, which is zero when the mid-point of the sloping side of v_1 coincides with a synchronization pulse (v_2) and assumes a positive or negative value when coincidence does not occur. This control voltage, as a bias on the control grid of the pentode, influences the frequency of the multivibrator and thus reduces the frequency deviation to zero.

Summary. The need in Belgium and the surrounding areas for television receivers suitable for two or more standards, has led to the design of a four-standard receiver, which has been brought on to the market in various types (e.g. type 17 TX 100A-70). Apart from the usual channel selector, the set is fitted with a standard selector, which gives a choice between the two Belgian standards, the French and the "Gerber" standard.

The vision channel contains for all four standards one and the same I.F. amplifier (38.9 Mc/s, bandwidth 4 Mc/s). Since both positive and negative picture modulation occurs, the video signal must be inverted somewhere; this is done at the picture tube. For the automatic gain control, a control tube derives a control voltage from the peaks of the synchronization pulses with negative modulation and from the peaks of the white in the picture with positive modulation.

The choice of 38.9 Mc/s as the I.F. for the vision amplifier leads to the following I.F.s in the sound channel: 27.75 Mc/s for the French standard and 33.4 Mc/s for the other standards. A second frequency transformation is used to bring these values down to a much lower one, viz. 7 Mc/s. The detector for FM is a conventional ratio detector, modified in such a way that it can be easily switched over to an AM detector with interference limiter.

The horizontal deflection is synchronized by means of automatic phase control by a flywheel circuit and the vertical deflection in the usual manner by means of an integrating circuit.

A COMPARISON BETWEEN REPRODUCED AND "LIVE" MUSIC

by R. VERMEULEN.

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Endeavours to realize fidelity in the transmission of music are of long standing. The subject aroused interest as long ago as 1881, when Parisians were given the opportunity of listening to telephone transmissions from the Grand Opera via an installation designed by Ader. Although still very imperfect, the installation had already one modern refinement: it was equipped for "binaural" hearing. From these beginnings stereophonic reproduction has been developed, nowadays generally recognized as essential to the natural reproduction of music.

The prerequisites for the natural reproduction of music have recently been re-examined in this laboratory. From alternate performances of "live" music and music reproduced with the most modern equipment in the same hall, it was found that in many cases the listeners could hear no difference between them and sometimes systematically confused the two.

Why is it that in spite of all technical progress in electro-acoustics, it is still possible to distinguish between the music heard from a loudspeaker and that heard in the concert hall? Many will have their answer ready to this question. They will point out that the music is distorted in the various links of the reproduction channel: microphones, amplifiers, tape recorder or gramophone, and above all by the loudspeakers. These devices fall short in the reproduction of very low and very high notes, and, moreover, they introduce alien sounds. The dynamic range is restricted on the one hand, by hum and noise, and, on the other, by combination tones, which arise from overloading.

It cannot be denied that even in the best reproductions of to-day these distortions are still present. Nevertheless we doubt whether our question can be answered by simply laying the blame upon the shortcomings of electro-acoustical apparatus. The possibility of measuring certain shortcomings objectively and quantitatively (such as the lack of high overtones) has been a great stimulus for improvement. But the uncertainty regarding the permissible magnitude of these imperfections makes it very tempting to regard them as the only cause of the musically not entirely satisfactory result. The danger then is that the electrical engineer will treat the electro-acoustical instrument as a link between a signal generator and a voltmeter, and impose requirements upon it which, from a musical point of view, are meaningless, or even erroneous. A typical example of such a misconception was the tendency, very prevalent among technicians at the time but now discarded, to regard hiss as a criterion for a good reproduction of high tones, and thus to consider a high noise level as a favourable rather than as an adverse characteristic.

The "hole in the wall"

It may therefore be wise to look for other answers to the above question. Are we sure, for example, that a reproduction channel with no measurable technical defects will be able to create the illusion that an orchestra is playing actually in the room? Might there not be other aspects, so far neglected, which impair musical appreciation more than minor technical imperfections?

Some investigation into the problem shows that it is possible to give a satisfactory reproduction of a single, small, spatially concentrated sound source, such as a human voice or one small instrument, such as a clarinet, on condition that it is reproduced at the original volume. With a small ensemble and especially with a large orchestra, however, something is lacking in the reproduction as heard from the loudspeaker. The reason is that even a perfect loudspeaker can do no more than imitate the vibrations picked up by the microphone, and thus the best result will only be equivalent to a hole in the wall of the concert hall. The sound that such an opening transmits is absolutely free from all electrical and mechanical distortion, and should therefore certainly be designated as "super-highest fidelity". Nevertheless, the concert-goer who has arrived too late and who has had to listen to the beginning of the concert through a chink in the door, is relieved when he can enter the concert hall. Thus, irrespective of technical imperfections, there is evidently something missing with music, originating from an extensive sound-source, that reaches our ears via a small opening.

It is now generally known that this lack of auditory perspective can be rectified by means of stereophonic reproduction. A number of articles on this subject have appeared in this Review, in 1939

and in later years. Before describing some comparative tests made with stereophonically reproduced music and "live" music, we may usefully recapitulate the principles of stereophonic reproduction. We shall start with its predecessor: binaural reproduction.

Binaural hearing

To improve loudspeaker reproduction it is firstly necessary to overcome the "hole-in-the-wall" effect. This can be done by using two microphones instead of one. The microphones may be placed as ears on an "artificial head" (*fig. 1*) and connected to a pair of headphones in such a way that the left ear hears the sounds picked up by the left-hand microphone and the right ear the sounds picked up by the right-hand microphone. In this way "binaural" hearing, i.e. with two ears (*fig. 2*), is restored. True, there are only slight differences between the sound heard in the left earpiece and that in the right, but they are quite sufficient to give the listener the impression that he is seated at the place where the artificial head is set up. He may, for instance, easily be given the sensation that he hears persons moving and talking behind him, although there is no one there. The impression may be so realistic that the listener has to turn round to convince himself that there is really no one there. But as soon as he does so, the shortcomings of this system become evident, viz: the whole acoustical world rotates with his head. To avoid this, one might arrange for the artificial head to turn with the listener's head, and tests have confirmed that this does in fact overcome the deficiency [1]); moreover, the listener can then distinguish between sound-sources in front of him and behind him, which he cannot do if he keeps his head still. The disadvantages of this otherwise ideal solution are, however, obvious: headphones are in themselves a nuisance — and the coupling of the

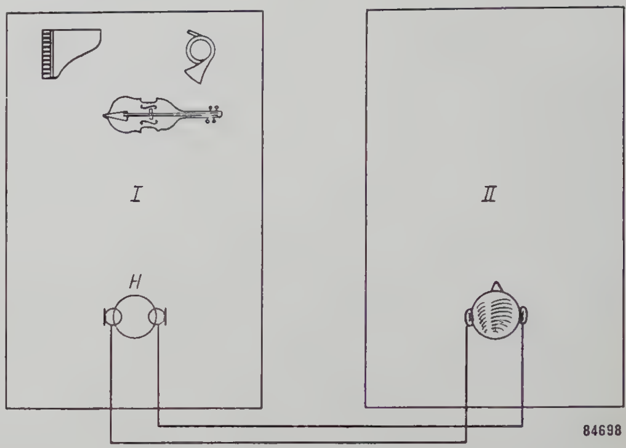

Fig. 2. Binaural hearing. The music played in room *I* is heard by the listener in *II* via headphones, each ear-piece of which is connected to a microphone. He thus receives an impression of auditory perspective, The microphones should preferably be fitted on an artificial head (*H*).

[1]) K. de Boer and A. Th. v. Urk, Philips tech. Rev. **6**, 359-364, 1941, in particular, pp. 360, 361.

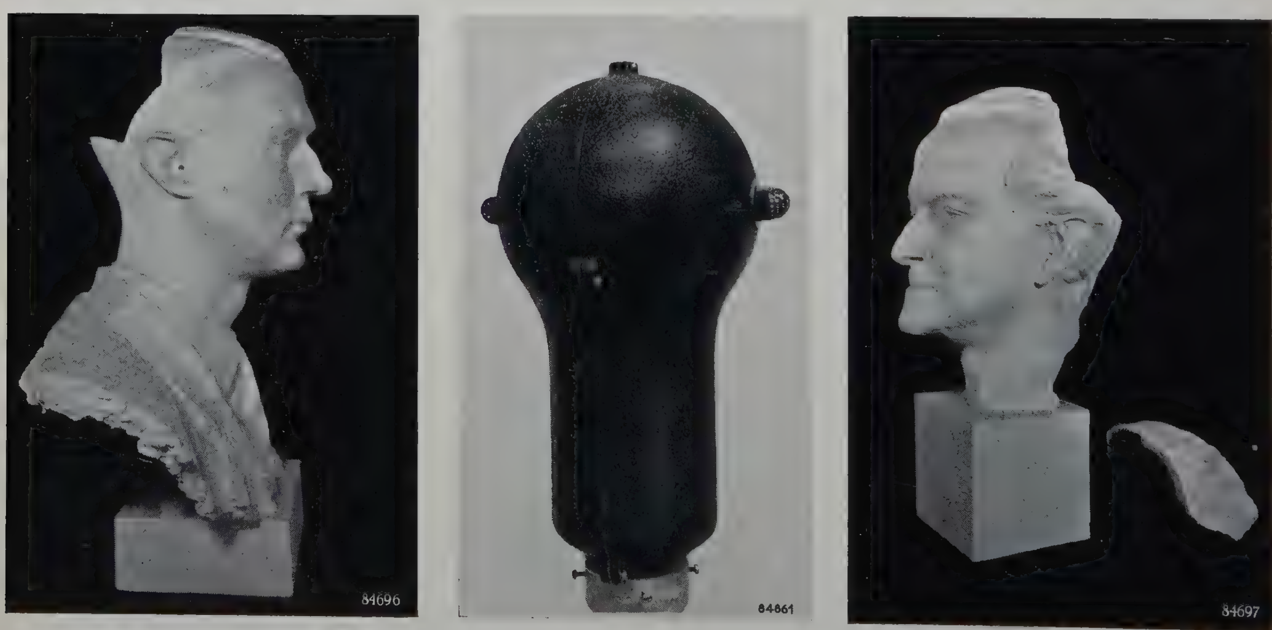

Fig. 1. Plaster heads, dating from the early days of stereophony and intended as experimental artificial heads. (They represent two workers who have contributed to the development of stereophony: on the left, K. de Boer; on the right, A. T. van Urk.) It was soon found that a sphere constitutes an adequate approximation to the human head. The photograph in the middle shows a modern artificial head.

artificial head with the listener's head would be quite impracticable. Nevertheless, these experiments were very instructive, showing as they did how essential is our binaural hearing to the sound impression received.

On the manner in which binaural hearing enables us to determine the direction of the sound-source, there have long been differences of opinion. It has been demonstrated by experiments that a time difference between the signals reaching the left and those reaching the right ear produces a sensation of direction, but others have shown that this is likewise the case with a difference in intensity. K. de Boer [2]), who has made a thorough study of the subject in this laboratory, was able to confirm that both parties were right, that is to say that differences both in time and intensity contribute to directional hearing. The remarkable thing is that these contributions are additive: the angle from which a sound seems to come, owing to a time difference, becomes greater or smaller as the effect of a superimposed intensity difference works in the same or in the opposite direction. It is even possible to let the two effects compensate each other; thus, a sound-source apparently heard from a certain angle as a result of a time difference, can be made to "return" to the centre by means of an opposing intensity difference.

Stereophony

A second remarkable effect noted by K. de Boer is that the sound stimuli which the ears receive from two loudspeakers, placed some yards apart and each connected to a microphone on an artificial head, are mentally interpreted as a single apparent sound-source, which appears to lie in between the two real ones. This helped to clarify the mechanism involved in obtaining three-dimensional acoustic effects using two loudspeakers instead of headphones (*fig. 3*). Stereophonic reproduction giving the impression that the sounds come from various directions was achieved by Fletcher and Stokowski as long ago as 1933 [3]).

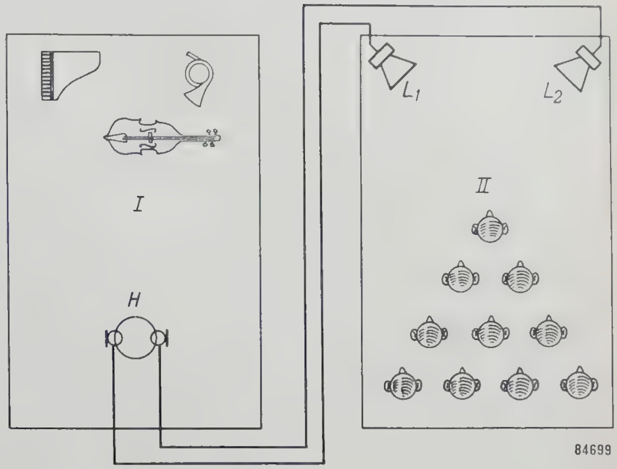

Fig. 3. Stereophony. Each microphone on the artificial head (H) in hall I is connected to its own loudspeaker (L_1, L_2) in hall II. Here too, the audience in II receives a spatial impression of the sound.

The explanation of the effect given at the time, however, is not entirely convincing. It may be briefly restated as follows. Suppose that in a concert hall a curtain is hung which is impervious to sound and which is provided, at the side facing the orchestra, with a large number of microphones. Each microphone is connected to a loudspeaker at the other side of the curtain (*fig. 4*). Sound waves picked up by the microphones are then radiated at the other side by the loudspeakers, and thus proceed as if the curtain were not present. If such a curtain with loudspeakers is set up in another hall, the same sound field will be set up as behind the curtain in the first hall. As there is a limit to the number of microphones, transmission channels and loudspeakers which can be installed, one has to make do with a rough approximation, for which three microphones and three loudspeakers were found to be sufficient.

Listening to the result of such an arrangement, and moreover on learning that the result is particularly good when using only two channels (two microphones and two loudspeakers), it is difficult to understand, if the above explanation were complete, how such a good approximation is obtained with so few channels. In our opinion we cannot leave out of consideration the psychological phenomenon that the four sound-stimuli received by both ears from the two loudspeakers are interpreted as coming from one single source [4]). It is thus not necessary to produce a

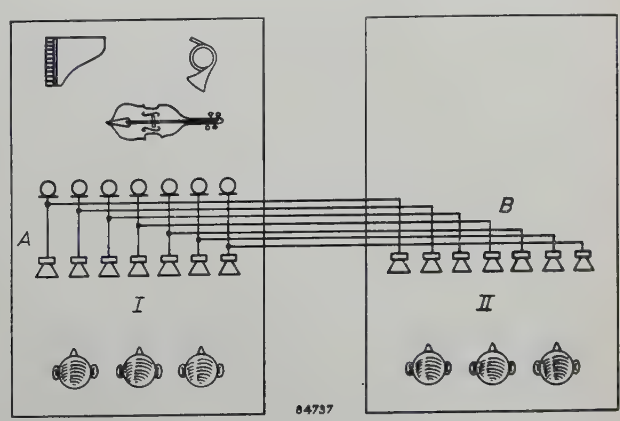

Fig. 4. Explanation of stereophony according to an American view. A is an imaginary "curtain", one side being fully taken up by microphones, the other by loudspeakers. Each microphone is linked via its own channel to the corresponding loudspeaker at the other side of the curtain, and also to a similar loudspeaker on "curtain" B in hall II. Thus, the same sound field is produced in hall II as in hall I. Practical stereophony, necessarily using only a small number of channels, would only be a rough approximation to the ideal case outlined.

[2]) K. de Boer, Stereophonic sound reproduction, Dissertation, Delft, 1940.

[3]) Symposium on wire transmission of symphonic music and its reproduction in anditory perspective: H. Fletcher, Basic requirements, Bell Syst. tech. J. **13**, 239-244, 1934.

[4]) K. de Boer, Stereophonic sound reproduction, Philips tech. Rev. **5**, 107-114, 1940.

replica of the sound in the room; it is enough if we aim at supplying the two ears with a set of signals that are perhaps different from the original ones but still create the same impression. According to the earlier explanation, three channels would give a better approximation than two, four a better approximation than three, and so on, whereas our experience is that two channels give a clearer and, above all, a "sharper" sound image than three. To avoid misunderstanding we should add that the use of more than two loudspeakers can still be advantageous, e.g. in order to produce a stereophonic effect for a *large* audience.

If the two microphones are mounted without the artificial head between them, the differences of intensity between the signals which they pick up become much smaller, these differences having been mainly the consequence of the shielding effect of the artificial head. The stereophonic effect must now rely primarily on the time differences. To suggest the same direction these must be strongly exaggerated, which can be done by making the distance between the microphones about three times as large as in the artificial head. It is surprising that the ear is able to interpret as directions such large time differences, although it can never have had the opportunity to acquire the faculty. In natural directional hearing the time difference is always less than 0.6 milliseconds and contributes only about 10% to the perception of direction. An artificial head thus supplies less abnormal signals than two separate microphones, and moreover, as a compact unit, it is easier to handle. The size of the artificial head is only in special cases the same as that of the human head. It can best be chosen in accordance with the set up and the size of the orchestra, following this empirical rule: if φ is the angle (in degrees) subtended at the head by the orchestra (*fig. 5*), then the horizontal diameter of the artificial head must be $(2000/\varphi)$ cm, and the distance between two freely-mounted microphones must be $(6000/\varphi)$ cm [5].

In the reproduction of music the *conscious* perception of direction, as made possible by stereophony, does not play a very significant role: after all, for the audience in a concert hall, appreciation of the performance is not critically dependent on the precise positioning of all the instruments. It is therefore not so very important that the directions are reproduced accurately. The reason why stereophonic reproduction gives a significant improvement is that the instruments are heard distinct from each other in space instead of as a muddle of sounds. Our "hole in the wall" has now become as it were a large window that enables the listener to survey aurally the whole of the orchestra.

[5]) K. de Boer, The formation of stereophonic images, Philips techn. Rev. 8, 51-56, 1946.

Another remarkable fact is that with stereophonic reproduction one can concentrate effortlessly on sound from a certain direction and detach one's attention from unwanted sounds (noise, hiss, reverberation, etc.) from other directions. It is striking how loud the noise in the studio seems when heard from one loudspeaker, how much more aware one becomes of reverberation, and how soon sounds become unintelligible when two or more persons are talking at the same time, whereas these phenomena are hardly noticed if one is in the studio oneself or if one listens to a stereophonic transmission.

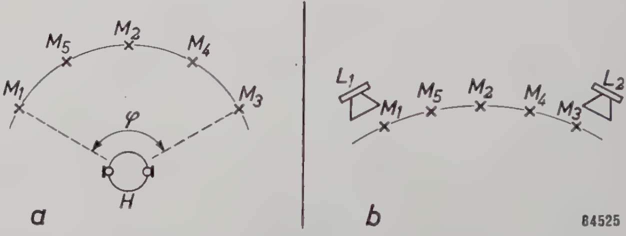

Fig. 5. *a*) The artificial head H "sees" an ensemble of musicians at a subtended angle φ. The most favourable horizontal diameter of the artificial head is $2000/\varphi$ cm (φ in degrees); the acoustic representation of the five musical instruments $M_1 \ldots M_5$ is then as shown in (*b*), between the loudspeakers L_1 and L_2.

Room acoustics

May we now expect that the stereophonic reproduction of orchestral music will be indistinguishable from the original — assuming, of course, that every attention has been paid to all details of the electro-acoustical installation?

This will certainly not be the case if the reproduction takes place in a hall or room whose acoustic properties are inadequate. It is generally recognized that the acoustics of a concert hall constitute an important element in the appreciation of music; we cannot therefore expect the imitation of an orchestra to do without this support.

It might be presumed that certain shortcomings in the acoustics of the room where the music is to be reproduced could be rectified by resorting to electro-acoustical aids. We shall leave this subject to a subsequent paper and proceed now to describe tests in which "live" and reproduced music were compared together. As both were played in the same hall, the influence of room acoustics was excluded.

Comparative tests

In order to ascertain objectively to what extent a stereophonic installation is capable of imitating actual musical instruments, we invited 300 persons to the Philips Laboratory to make a comparison

between the reproduction of stereophonically recorded pieces of music and the same pieces played by a small ensemble, seated behind a thin but opaque curtain. The greatest care was spent on the recording of the music, so that it would really be the best possible replica of the ensemble, particular attention being paid to the setting up of the artificial head. Naturally, the reproduction had to be just as loud as the actual music. The entire reproduction apparatus remained in operation all the time in order to prevent switching clicks and perhaps a change, however small, in the level or the character of the room-noise, from giving some listeners a clue. The recordings (on tape) were therefore made with long periods distributed arbitrarily between them; during these blank periods, the tape still running, the live music was played by the musicians.

The procedure was a follows. The same, short piece of music (15 to 30 seconds) was rendered twice, both stereophonically and by the musicians, but in arbitrary order, each piece of music being indicated in chronological order as "reproduction A" and "reproduction B" ("reproduction" thus includes the live performance. The listeners were not aware that "live" music would be played). Immediately afterwards, there followed, as "reproduction X", a repetition of either A or B. The listeners then had to answer, within about one minute, the following questions presented to them on a questionnaire:

I) Was X the same as A or the same as B?

II) Which of the two reproductions, A or B, was the more natural?

The first question merely requires the listener to hear a difference between the actual and the reproduced music, whereas the second question requires that he should moreover have an idea of how "live" music sounds. At each session, ten pieces of music of different kinds (chamber music, dance music) were played, the number of musicians varying slightly.

After the experiments were concluded, the right answers returned were marked with the number 1 and the wrong ones with 0 and the means taken of the totals. The result was 0.75 for the first question and 0.71 for the second question. If it is borne in mind that an average of 1 for the first question would mean that every participant in the experiment always heard a difference between "live" and reproduced music, and that a result of 0.5 means that no participant heard any difference whatsoever and everybody was therefore guessing, it appears that the result obtained (0.75) lies midway between these two extremes. Thus, the average of 75 correct answers out of a hundred cases can be comprised of 50 correct "decisions" and 25 lucky guesses. Relatively few persons (16%) were able to hear the difference infallibly, and even they found it rather difficult. To recognize the "live" music as the more "natural" appeared to be even more difficult, as was shown by the average of 0.71 for the second question.

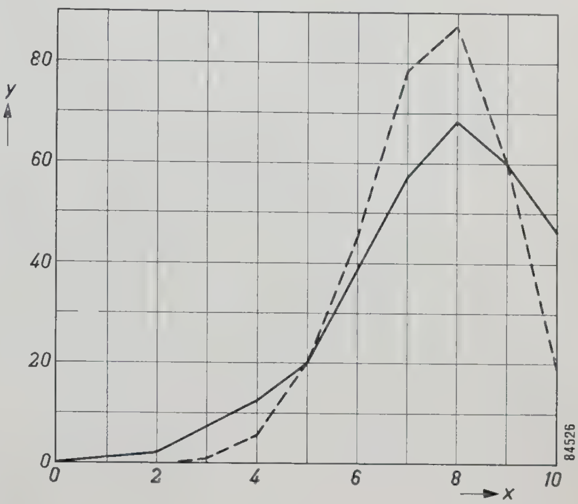

Fig. 6. Full curve: number of persons y, on an average per series of ten tests, that gave x correct answers to question I, plotted as a function of x. Dashed curve: probability distribution (binomial curve) taking 0.75 as an average of all answers to question I. Total number of participants in the tests: 310.

The results of a statistical treatment of the answers are represented graphically by the full lines in *fig. 6* (question I) and *fig. 7* (question II). The number of listeners, y, who gave x correct answers to the ten questions is plotted as a function of x; a total of more than 300 persons participated in the experiments. If there had been no mutual differences between the participants, and no differences in

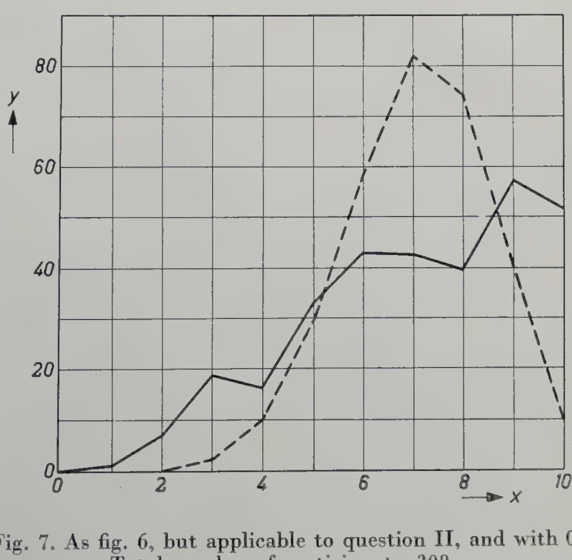

Fig. 7. As fig. 6, but applicable to question II, and with 0.71 as average. Total number of participants: 308.

difficulty between the successive tests, we should have had a curve determined exclusively by chance, that is to say a binomial curve. This curve is shown by a dashed line in both figures, for an average result of 0.75 and 0.71 respectively. It can be seen that the full curve in fig. 6 follows very roughly the binomial distribution. On the extreme right the observed curve lies somewhat above the binomial curve. This means that a group of persons had a more than average power of discrimination and gave the right answer relatively often. On the other hand there is a large group that often heard no difference at all and a small group that systematically gave the wrong answers. A more detailed analysis leads to the conclusion that for the persons individually the chance of giving a correct answer varies between 0.55 and 0.95.

The much greater disagreement between the curves for question II is doubtless attributable to the fact that, to answer this question correctly, considerable familiarity with the sounds of musical instruments is required, a familiarity which can, on the whole, only be expected of professional and amateur musicians. The curve in fig. 7 lies, at the left, appreciably above the binomial, which means that a number of persons did indeed notice a difference, but systematically took the reproduction to be the live music, and conversely.

It might be objected that the foregoing conclusions are drawn from tests made with only a small ensemble and therefore may not be extended out-of-hand to apply to a large orchestra, because its dynamic range is so much larger and consequently more difficult to deal with. In a subsequent article we shall discuss experiments in which a large orchestra was involved — although, it may be added, the purpose of the experiments was not to reproduce the music in another hall, but to improve the acoustics of the hall in which the orchestra was playing. On this occasion recording and reproduction were again stereophonic. No systematic inquiry was held on the results, so that no figures can be offered, but the opinion of the listeners gave us the impression that this reproduction too was deceptively like the real thing. We therefore feel justified in concluding that it is possible to keep the imperfections of electro-acoustical equipment at such a low level as to make them almost imperceptible, even in the case of a large orchestra.

Summary. The author poses the question: why, in spite of the technical progress made in electro-acoustics, is there still an audible difference between the music played in the concert hall and its reproduction via a loudspeaker. The answer should not be sought in the first place in minor technical imperfections, but rather in the two following facts: 1) the instruments of the orchestra are not heard separated because the sound emerges from the small opening of one loudspeaker, and 2) the room where the music is reproduced is often acoustically inadequate.

As has long been known, the first drawback can be remedied by stereophonic reproduction: the sound is picked up by two microphones — preferably placed on an artificial head — and is reproduced, via separate channels, by at least two loudspeakers.

To ascertain in how far stereophonic reproduction can be distinguished from "live" music, comparative tests were carried out, in which strict vigilance was exercised to ensure that the persons taking part in the tests (more than 300) were given no clue as to whether they were listening to "live" music (a small ensemble, concealed from view) or to a stereophonic reproduction thereof. Ten tests were made per session and, for each test, the participants had to give written answers to two questions. Question I concerned the ability to discriminate between the "live" music and the imitation, and question II the "naturalness" of the music. The answers were treated statistically. The general conclusion reached is that, of the average of 75 correct answers out of a 100, 50 are attributable to discernment of the difference and 25 to guessing. Relatively few people (16%) can identify the difference with certainty, however, and then only with difficulty.

A postscript to this article reports on similar experiments carried out in the Amsterdam Concertgebouw and in the "Academisch Genootschap" building in Eindhoven.

Postscript. After the above article had been prepared, two somewhat differently arranged demonstrations with "live" and reproduced music were made, on the instigation of G. Slot and with the cooperation of the Apparatus Division's Acoustical Development Laboratory, in the "Kleine Zaal" (Small Auditorium) of the Amsterdam Concertgebouw and in the "Academisch Genootschap" building at Eindhoven.

As gramophone music was also involved in the demonstrations, no stereophony was employed, but an attempt was made by means of a specific arrangement of the loudspeakers to create the best possible impression of auditory perspective. The installation comprised a type EL 3500 tape recorder (tape speed 76 cm/s), a 60 W amplifier of very high quality and two AD 5002 loudspeaker sets. Each of these sets consisted of an acoustical box with two 9720 loudspeakers (diameter 21 cm) for the frequency range from 30 to 400 c/s, and two high-note projectors, each equipped with one 9710M loudspeaker, for the frequency range from 400 to 20 000 c/s.

For certain pieces, a mixture was played of direct and reproduced music. There was, for example, a piano-piece for four hands, one part of which had been previously recorded and was reproduced while the other was actually being played. Then there was the "farewell" piece, which had been recorded in such a way that the musicians were able to leave the platform one by one during the performance, while the music went on without interruption. They did this, not as soon as their part had been taken over by the reproduction, but some bars later, making sham movements in the meantime. It appeared that the audience found it almost impossible to indicate with certainty the moment of take-over.

In the "Academisch Genootschap" building at Eindhoven an enquiry was held after the interval, which is briefly reported here. Four pieces were played by a small ensemble, of which one or two of the instruments had been previously recorded. The non-playing musicians again made sham movements and the hall was in partial darkness. The persons present were requested after each number to indicate on a questionnaire for each instrument whether they believed it had actually been playing or whether it had been reproduced.

When judging the results given below it should be borne in mind that, as the reproduction was not stereophonic, some clues were given by the different directions from which the sounds of the musical instruments and of the loudspeakers reached the audience. In the front half of the hall especially, this factor was by no means negligible.

Out of an audience of 130 persons, 107 completed questionnaires were returned. The total number of wrong answers amounted to 378. If the 107 persons had only guessed, the number of wrong answers would have been 720. We set out below the results compiled for the instruments individually.

Double bass. With the low notes produced by this instrument it is very difficult to discern the direction from which the sound originates, so that the results in this case give the fairest picture of the quality of reproduction. It is therefore not surprising that the largest number of wrong answers, viz. 150, were returned for the double bass. In the following table, the actual figures are set out in the column headed "In reality", and the figures based on pure chance are given in the column headed " If guesswork". It can be seen that the differences are slight, so that we may assume that the audience was mainly guessing.

	In reality	If guesswork
Bass taken for reproduction . .	61	54
Reproduction taken for bass . .	89	90
Reproduction recognized as such	18	18

Piano. For the piano, 74 wrong answers were returned. In the following table we give an additional column headed: "If half guessed"; the figures shown in this column, which are very close to the actual figures, would apply if half the audience had only guessed.

	In reality	If guesswork	If half guessed
Piano taken for reproduction	27	63	27
Reproduction taken for piano	47	84	45
Reproduction recognized as such	60	21	62

Accordeon. The number of wrong answers given for the accordeon was 62, against 74 for the piano. The distribution was approximately the same as for the piano.

Saxophone. Only 48 wrong answers were returned for the saxophone. There is reason to believe that the recording was not so good as it might have been. Later tests have in fact confirmed this, showing that in this case a great deal depended upon the positioning of the microphone [6]).

Percussion instruments. Although the directional effect as regards cymbals and brushes was very distinct, there were nevertheless 44 wrong answers.

Only three out of 130 persons returned a fully correct questionnaire. It may be assumed that the 23 persons who failed to hand in a questionnaire were unable to discern any difference, so that the actual result was probably even better than emerges from the above figures.

An interesting detail worth mentioning in conclusion is that the average number of wrong answers given by the 42 active music-lovers present amounted to 3.0, as against 3.8 given by the 65 others. No difference worth mentioning could be ascertained between the answers given by the technical (mainly radio and sound engineers) and non-technical members of the audience.

[6]) In the high register, the saxophone has a very pronounced directional effect. See H. F. Olson, Musical Engineering (Mc. Graw Hill, New York 1952), page 234.

A SIMPLE ULTRAMICROTOME

by H. B. HAANSTRA.

578.67:621.385.833

The cutting of very thin sections with a microtome, long practised in optical microscopy, is now being applied to specimens for the electron microscope. Since the resolving power of the electron microscope is about 100 times greater, ultra-microtomes are necessary which produce sections about 100 times thinner than the normal microtomes, viz. of a thickness of the order of 0.01 microns (100 Å). It is remarkable that it has been found possible to do this with comparatively simple apparatus.

Specimens which are to be studied in the microscope by transmitted light, must be sufficiently transparent to light and must not contain too many discernable details behind one another in the direction of vision. The permissible thickness is thus related to the resolving power. For the optical microscope, with a resolving power of the order of $^1/_2$ to 1 micron, specimens a few microns in thickness are required.

Cutting such thin slices (sections) of objects is an old technique, particularly for biological work. Instruments for the making of sections were in use as early as the 18th century (cylinder microtomes). With the present types of microtome, which are part of the standard equipment of biological laboratories, one can make fairly reproducible sections of a thickness of a few μ, in some cases of 1μ.

In the development of electron microscopy, an analogous problem has been met with from the outset. The image is formed in a somewhat different manner; the contrast occurs through the varying degree of electron scatter due to the varying density of the object; moreover, the apertures of the incident beams are extremely small so that there is a much greater depth of focus than in optical microscopy. The criteria for the permissible object thickness are, however, analogous to those for optical microscopes: the parts of the object in which details must be distinguishable, must transmit sufficient electrons of the energy employed (in most microscopes 50 to 100 keV), and there must not be too many details piled up behind one another. In view of the different manner of image formation the latter condition is even more important here than in optical microscopes: in parts of the object lying behind others, the electrons may suffer repeated scattering, so that they "forget" the information which they should transmit and only contribute a general veil to the image. At worst, the detail looked for is obscured; at best, the superimposed sharp images of details lying in different planes makes interpretation more difficult.

Even for early electron microscopes, which reached a resolving power of a few 100 Å, sections of 1μ (10 000 Å) were much too thick. For a long time, therefore, research with the electron microscope was limited to objects which did not need cutting, for example, very small isolated bodies or objects in the form of very thin films (organisms such as bacteria or viruses, vapour-deposited materials or collodion films, etc.), or surfaces of which very thin replicas could be made. Innumerable techniques have been developed for this purpose and a great deal of research carried out in this way [1]). In some fields, however, in particular anatomy and its subsidiary field histology (study of tissues), no advantage could be taken of the high resolving power of the electron microscope since their specimens cannot very well be prepared for investigation other than by making sections. With a resolving power of 50 Å, as quite normally attained in present electron microscopes, sections of a thickness of 200 Å or even less are needed.

Refinements of the classical microtome made possible sections of a thickness of 0.1 μ (1000 Å) [2]), and in recent years Porter et al. in America and Sjöstrand in Sweden have succeeded in constructing apparatus which will make sections of less than 200 Å in a reproducible manner [3]). It is not unreasonable to say that this has meant the beginning of a new era for the electron microscope. Already a vast amount of research has been done with the help of the new technique.

The cutting of successive slices of, for example, 100 Å thickness means, when one considers it, that one is setting out to cut large organic molecules by mechanical means. It will be immediately assumed that the "ultramicrotomes" for this pur-

1) For a survey, see: D. G. Drummond, The practice of electron microscopy, Royal Microscopical Society, London 1950.
2) D. C. Pease and R. F. Baker, Proc. Soc. Exper. Biol. Med. **67**, 470-474, 1948.
3) K. R. Porter and J. Blum, Anat. Record **117**, 685, 1953. F. S. Sjöstrand, Experientia **9**, 114, 1953.

pose must be instruments requiring the utmost precision in construction and thus rather costly. Surprisingly enough, however, it is possible to achieve this performance with a very simple instrument, the construction of which involves no exceptional precision work. A prototype of the instrument to be described here, which will be marketed in due course, is shown in *fig. 1*.

Construction of the new ultramicrotome

The ultramicrotomes made by Porter, Sjöstrand and others, distinguish themselves from the classical microtomes by the manner in which the motion of the object is obtained. In the classical method, where the displacement is produced by a screw which causes the specimen holder to move along guides, the reproducibility is limited principally by the variation in thickness of the oil film between the moving surfaces which require lubrication. This effect is entirely avoided in the ultramicrotomes of Porter and Sjöstrand by obtaining the displacement from the thermal expansion of a metal rod, at the end of which the specimen is mounted [4]). Starting at room temperature and supplying heat at a constant rate, one obtains for some time a very uniform, continuous change of length of the rod. If the extremity of the rod with the mounted specimen is then periodically allowed to carry out the cutting motion past the fixed knife, very thin sections of constant thickness are obtained (*fig. 2a*).

A complication occurs here just because the change of length is continuous. After a cut, the specimen has to be brought back to its original position with respect of the knife. Between the moment of cutting and that of return, the forward motion of the specimen has continued. The specimen may not therefore move back along the same path as it travelled in the cutting motion, since it would scrape along the knife and the surface of the next section would be destroyed before it was cut off.

In one of the existing ultramicrotomes this problem was solved by mounting the object excentrically on a vertical rotating disc (fig. 2*b*). The specimen makes contact with the knife on the downward part of its path and not on the upward part. This construction, however, once more makes use of journal bearings, which threaten the reproducibility through their lubrication and possible vibration. To minimize this source of error the most extreme precision in finish was necessary.

In the new microtome described here the displacement is also obtained by thermal expansion. The return stroke, however, follows the same path as the cutting stroke, the necessary clearance between

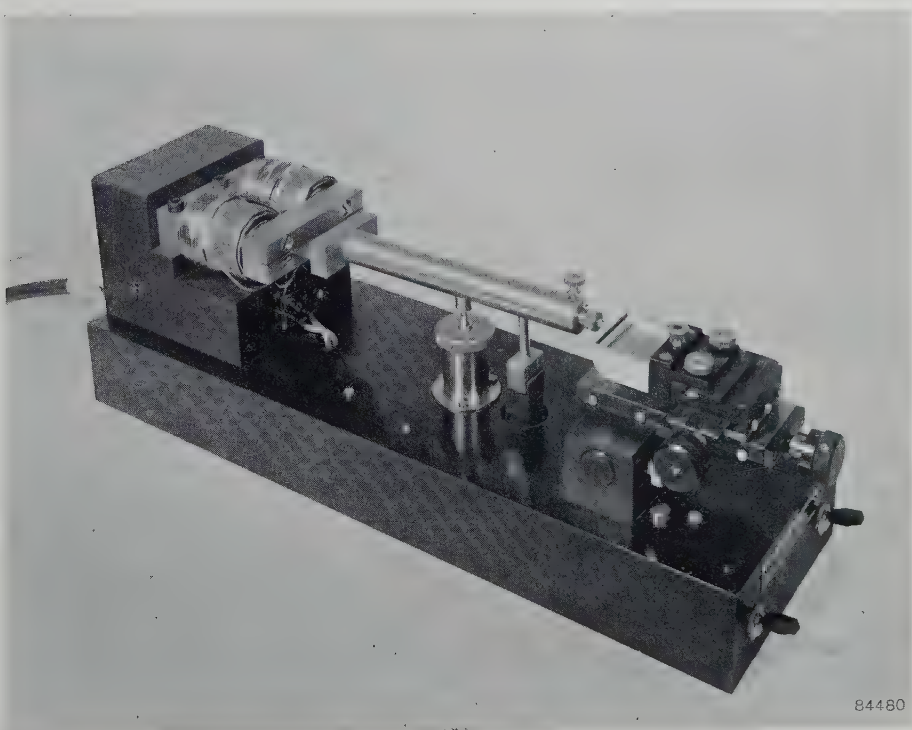

Fig. 1. The new ultramicrotome designed at Eindhoven.

[4]) This principle was first applied by G. B. Newman, E. Borysko and M. Swerdlow, J. Res. Nat. Bur. Stand. **43**, 183-199, 1949.

specimen and knife on the return journey being produced by magnetostriction. The rod on which the specimen is mounted is magnetized after each cutting stroke, before it moves upwards again; the magnetization causes shrinkage, so that the specimen is pulled back slightly; when it reaches current of several amperes, which produces the periodic change of length according to the diagram of fig. 3. At the same time, the heat dissipated in the winding warms the rod to the desired degree. The intermittent supply of heat means that the distribution of temperature within the rod does not

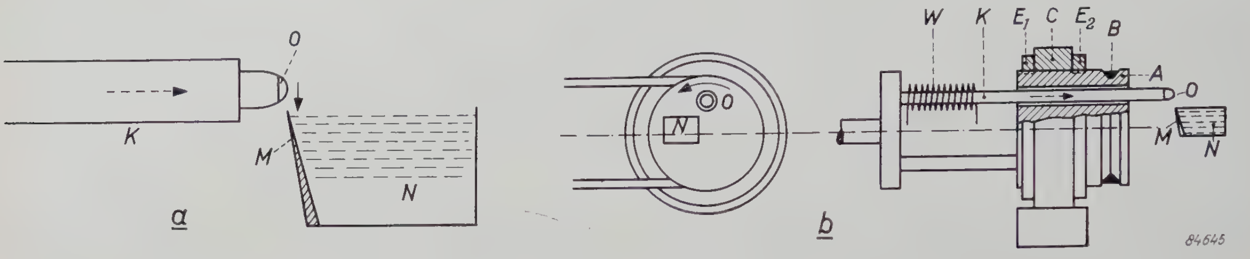

Fig. 2. *a*) Simplified diagram of an ultramicrotome with displacement by means of thermal expansion. The knife is a safety-razor blade, (M) sharpened and polished in a special way, or in some cases, a knife specially made for this purpose of glass or diamond. The knife is fixed. The specimen (O) is mounted on a metal rod (K) which holds it above the knife. The thermal espansion of the rod (- - -➤) produces the forward motion of the specimen, so that when the rod moves downwards a thin section is cut. A small dish (N) is fixed to the knife and is filled with liquid (usually 20% alcohol) up to the cutting edge of the knife. The sections, when cut, slide off the knife on to the surface of the liquid and usually form a chain. They can easily be transferred from the liquid surface to a formvar film on a specimen carrier. *b*) In an instrument developed by Sjöstrand the rod K rotates with the specimen O. This is effected by the pulley D driven by the belt B. The pulley runs in bearings in the fixed ring C and is fixed in the axial direction by the rotating rings E_1 and E_2. Electric heating (winding W) causes the rod to expand. The knife M and the dish N are so placed that the specimen only touched the knife on its downward path. On the upward path, the specimen passes behind the knife.

the top position, the magnetic field is switched off and the rod re-assumes exactly its original length — except for the thermal extension, which has continued in the meantime. The diagram in *fig. 3* illustrates schematically the successive motions.

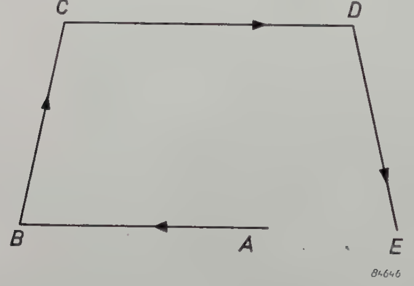

Fig. 3. Schematic diagram of the motion of the specimen in the new ultramicrotome (not to scale).
$AB \approx$ 1-2 μ: retraction by magnetostriction.
$BC \approx$ 3 mm: upward movement of specimen carrier.
$CD = AB$: magnetostriction released.
$DE = BC$: cutting stroke (specimen carrier drops).
The distance $AE \approx$ 50-200 Å corresponds to the thermal expansion during the whole cycle $ABCDE$.

The whole arrangement now becomes extremely simple, because the same current is used to produce the gradual heating and the magnetostriction. The rod, whose thermal expansion produces the displacement, is made of nickel, which exhibits a strong magnetostrictive effect. A coil is wound on the rod and through it flows an intermittent change uniformly throughhout; a slight ripple is superimposed on the heat passing into the rod. However, the thermal capacities of the system are so large that the resulting thermal expansion occurs uniformly with the time.

To conclude this general description it may be noted that in this instrument the unfavourable effects of lubricated bearings, sliding surfaces, etc., have been eliminated entirely, even in the up-and-down motion of the specimen. Instead of the more obvious hinged construction, use is made of a broad piece of spring strip; the up-and-down movements are produced mechanically. *Fig. 4* gives a picture of the arrangement of the whole instrument. The nickel rod or core K, surrounded by a coil, produces the required displacement of the object by thermal expansion and periodic magnetostriction. The

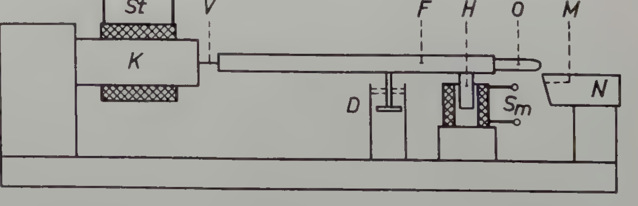

Fig. 4. Diagram of the complete instrument. M knife, fixed; O specimen carried by the arm F, which is fixed to the nickel core K by the spring strip V; St coil for heating and magnetizing the core K; Sm solenoid by means of which the permanent magnet H is periodically raised; D oil damping.

specimen (O) is mounted on a brass arm (F) of constant length connected to the nickel rod by the spring strip (V). The arm F carries near its free end a ferroxdure magnet (H), which is inserted into a vertically fixed solenoid. An intermittent current is passed through the solenoid, forcing the magnet and the end of the arm upwards at intervals and then releasing them. During the downward movement the specimen (O) moves past the fixed knife (M) and a section is cut. It is of importance to notice that the cutting motion is initiated by gravity and the elasticity of the spring, two forces which may be assumed to act repeatedly in a reproducible manner. To prevent the arm F from carrying out free oscillations, damping is introduced in the form of a piston moving in an oil cylinder (D in fig. 4). By adjusting the magnitude of this damping, the speed at which the specimen passes the knife in cutting can also be controlled.

The excitation current for the solenoid and that for the heating and magnetostriction coil are both derived from a D.C. source, which is periodically switched on and off by two small commutators. The required intermittent action is thus obtained, and since the two commutators are mounted on the same spindle which is driven by a small motor, the necessary synchronization between the two currents is ensured: the ferroxdure magnet is raised each time after the nickel core has been magnetized and the specimen retracted; the magnet is released, and the section cut, after the core has been demagnetized.

The thickness of the sections

The energy dissipated in the heating coil, and thus the speed at which the nickel core expands, is independent of the speed of rotation of the commutators. However, the number of sections made per second is proportional to this speed of rotation, and by altering the speed of the motor, the thickness of the sections can be varied quite simply. Another method is to alter the current in the heating coil. (This also causes a change in the magnitude of the magnetostriction, but in practice this is always so much larger than the thickness of a section, see fig. 3, that there is never any fear of the specimen touching the knife on its return journey.)

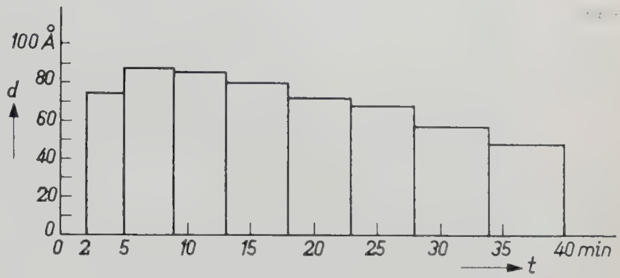

Fig. 6. Average thickness d of the sections obtained during thermal expansion of the nickel core over a period of 40 minutes. The thickness is calculated from the measured displacement of the specimen over the given periods and the number of cuts made (in the present case, 49 per minute.) The sections cut during a period of about 20 minutes are of fairly constant thickness, viz. 80 ± 10 Å.

It is naturally important to be able to estimate the thickness of the sections. This is very difficult to do during the actual cutting. The following method was therefore introduced. First, the knife was observed through a microscope to ensure that, at a particular power dissipation in the heating coil and a particular speed of rotation, sections were cut continuously for about 40 minutes. After the nickel core had cooled down, the knife was replaced by the pick-up of a displacement meter type PR 9300; the solenoid (Sm, fig. 4) was removed (but

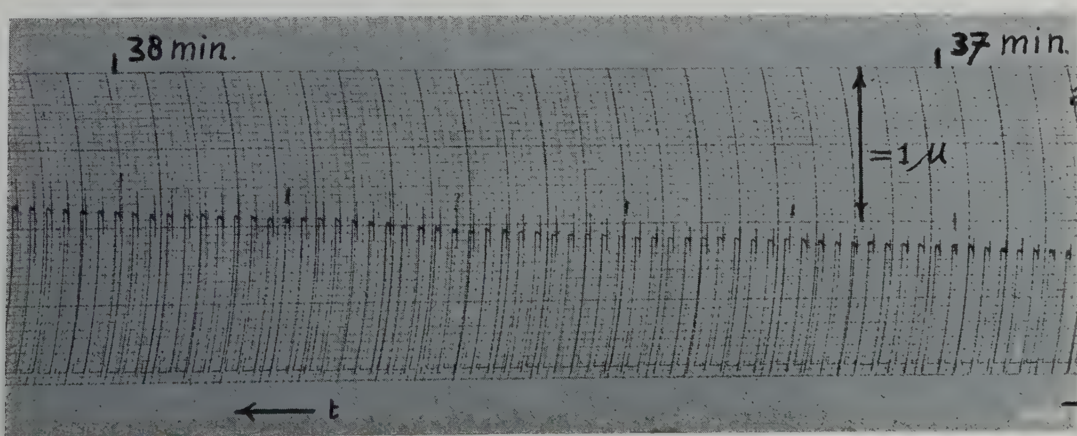

Fig. 5. Section of strip chart recording the displacement of the object during the 40 minutes in which the nickel core was heated. The displacement was measured with an inductive displacement pick-up and meter.

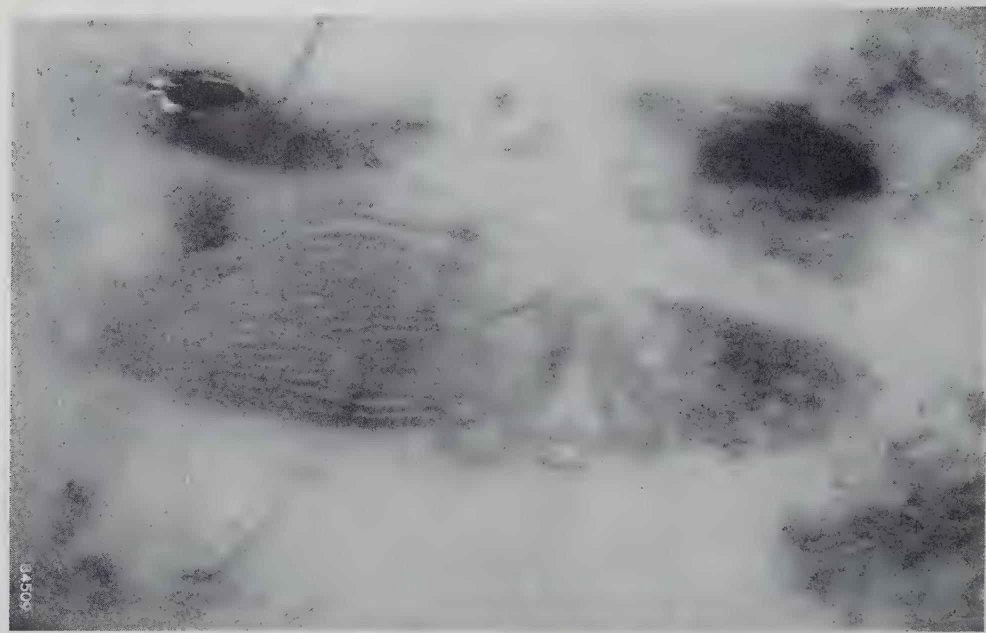

Fig. 7. Section of a chloroplast from a type of lettuce (Lactuca sativa). The chloroplasts are treated with a 1% solution of osmium tetroxide (OsO_4) of $pH = 7.4$ at 4 °C and then dehydrated with ethanol/water mixtures rising to 100% ethanol. From the ethanol they are transferred to a mixture of 95% butylmethacrylate and 5% methylmethacrylate monomers and then polymerized at 45 °C with the aid of 1% benzoyl peroxide as catalyst. Thus embedded, the chloroplasts are cut in the ultramicrotome; after that the sections were transferred to a specimen carrier.

When treated with the OsO_4, the latter is more reduced in the fat-containing parts of the tissue than in the other parts. The photograph shows a chloroplast grain, built up of alternating layers of lipoid (dark) and protein. Magnification 67 000 ×.

remained connected, so that the electrical circuit was unchanged). For about 40 minutes, the displacement measured by the pick-up was recorded on a recording instrument. A small section of the recording strip is reproduced in *fig. 5*. The very uniform thermal expansion with the magnetostrictive change of length superimposed on it can be seen. About 2 minutes are required after switch-

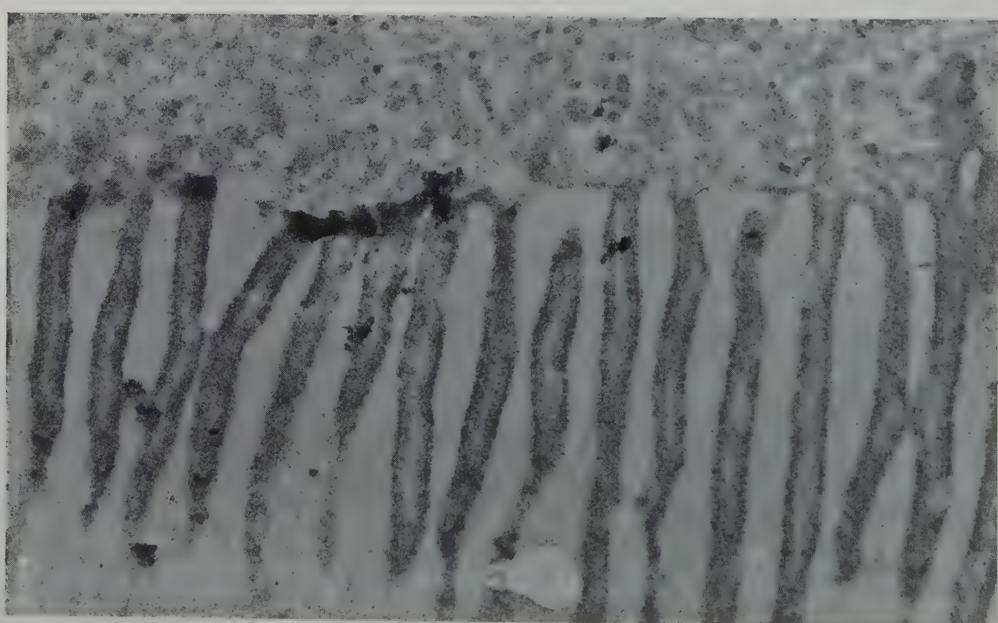

Fig. 8. Section of the fringed edge of the intestinal epithelium of a type of Ascaris, a parasite living in the intestines of pigs. Treated as in fig. 7; magnification 15 000 ×. (Specimen provided by Prof. L. H. Bretschneider, Zoological Laboratory of the University of Utrecht.)

Fig. 9. Section of aluminium. An aluminium rod was shaped so that a small pyramid (about 0.3 mm high, base 0.3 × 0.3 mm) stuck out at one end. The tip of this was cut with a diamond knife. The angle between knife and specimen was very critical; the best adjustment was found empirically. No further particulars can yet be given about the structure seen in the photograph. Magnification 24 000 ×.

ing on before the heating coil transmits sufficient heat to the nickel core: the expansion was only 0.2 μ in the first 2 minutes. In the following 3 minutes, the core expanded 1.08 μ. The cutting speed being 49 sections per minute, the average thickness of the sections during these 3 minutes was 73 Å. The average thickness, calculated in an analogous way, for a number of successive intervals, is shown in *fig. 6*. It is seen that the instrument, during a period of about 20 minutes, cut sections of a reasonably reproducible thickness of 80 ± 10 Å. The figure shows, incidentally, that it is quite possible to make sections of 50 Å.

Figs 7, *8* and *9* show a few electron microscope exposures of sections made with the ultramicrotome described. Details are given in the captions.

Summary. Biological specimens, such as parts of tissues, can only be made accessible to microscopic investigation by cutting sufficiently thin sections. The development of ultramicrotomes (by Porter and by Sjöstrand) with which sections of 200 Å and less can be made, makes it possible to take advantage in the above field of the enormous resolving power of the electron microscope. In these ultramicrotomes the displacement is effected by thermal expansion of a metal rod which carries the specimen. In order to prevent the knife from scraping the specimen surface on the return stroke, a rather complex mechanical arrangement is used, which must be constructed with the utmost precision. In the new ultramicrotome described in this article, the clearance is obtained in a very simple way by magnetostriction of the nickel core which carries the object. The periodically switched magnetizing current produces at the same time the heating necessary for the displacement by thermal expansion. The up-and-down movement of the specimen for the cutting is provided for by mounting the specimen carrier arm on a spring strip fixed to the nickel core. The instrument thus has no bearings or sliding surfaces. Measurements with an inductive displacement meter have shown that in a particular case, about 1000 sections were made in 20 minutes, of thickness 80 ± 10 Å. Sections down to about 50 Å in thickness are attainable.

A HIGH-VACUUM TAP WITH SHORT OUTGASSING TIME

621.646.6:621.52

The better the vacuum achieved in the pumping-out of electronic tubes, the better, as a rule, the quality of the tubes; they will have a longer life, better uniformity and — of prime importance with transmitting valves, rectifiers and X-ray-tubes — be able to withstand higher voltages. Improvements in vacuum technique are therefore constantly being sought.

One weak point in the high-vacuum installation is the taps, which by their very nature are indispensable items. A glass tap of normal construction is shown in *fig. 1*. In order to make it easy to turn the tap plug in the housing, and at the same time to provide a vacuum-tight seal, it must be lubricated from time to time with a special tap-grease. After the greased plug is set in place and the pumping

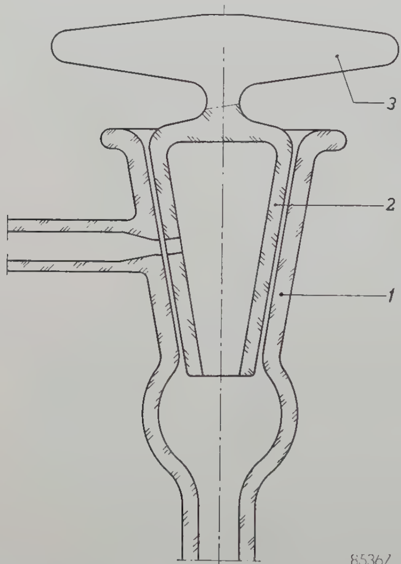

Fig. 1. Glass high-vacuum tap of normal construction. *1* tap housing. *2* plug. *3* handle.

installation has been put to work, some considerable time ensues before a vacuum of, say, 10^{-6} mm Hg is reached; this may quite well involve a period of some ten days. Depending on the type of vacuum grease used, it is necessary to renew this at least every six months, and sometimes even within one month; several days are then again necessary to re-attain the vacuum.

The cause of this long pumping-time is the fact that the air, which is partly absorbed in the grease-layer and partly within it in the form of air-bells, is liberated only very slowly. Only a very small section of the grease-layer is in contact with the evacuated space, and the air is rapidly extracted from this section. The remainder is enclosed between plug and housing, and can thus only find an outlet along a very narrow path, some centimetres long [1]).

An improved vacuum tap has now been designed in which *the whole greased surface can be exposed to the vacuum*. The air then nowhere has to find an

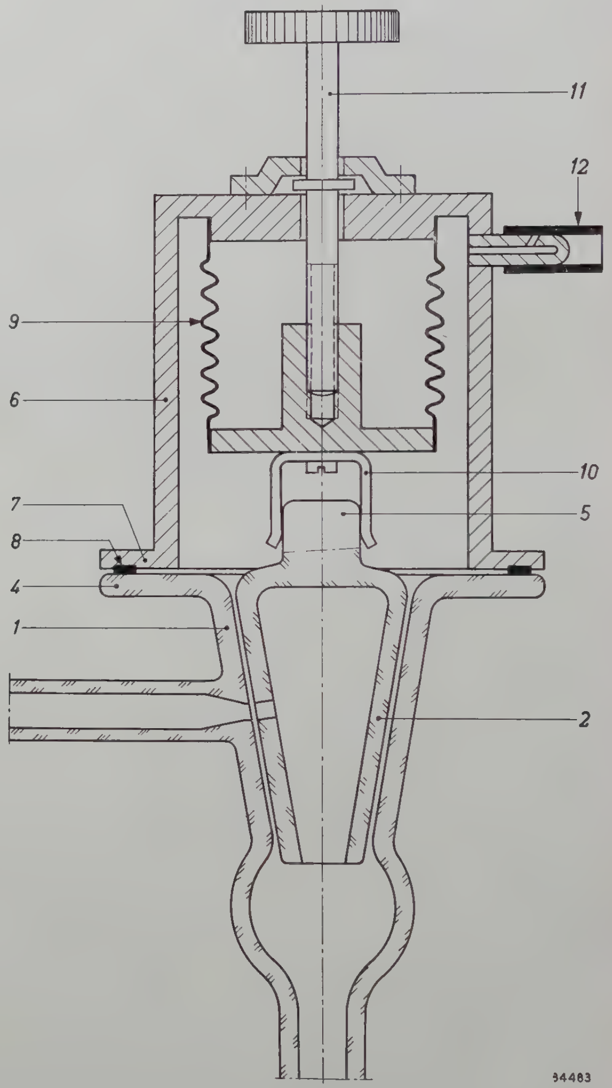

Fig. 2. New high-vacuum tap with short outgassing time. *1* tap housing with glass flange *4*. *2* plug with square, solid head *5*. *6* metal cap, with flange *7*, carrying sealing ring *8*. *9* metal bellows. *10* sprung fork. *11* adjusting screw. *12* valve. After the tap is outgassed, the cap is removed.

[1]) The whole process may be somewhat speeded up by turning the plug slightly now and again during pumping; this at least gives part of the grease in other places an opportunity to lose its air rapidly (this turning stretches out the air-bells, which may be seen as stripes through the glass), and reduces also the sudden increases in pressure which later occur when turning the tap.

escape route longer than the thickness of the grease-layer, which is only of the order of 0.1 mm.

Fig. 2 shows a cross-section of the new tap. The tap housing is provided with a flange, which is ground flat. The greased plug is inserted in the housing, turned round a few times (to distribute the grease evenly) and taken out again, so that the excess grease can be removed; it is then replaced in the housing. A metal cap is placed over the tap; the flange of the cap rests on the glass flange, to which it is temporarily fixed with spring clips. The inside of the cap carries a metal bellows, bearing a sprung fork which, when the cap is attached, grips the square head of the plug protruding from the plug-housing. By means of an adjusting screw, the bellows may be contracted, thus withdrawing the plug from its housing. The pumping installation is now set working. Since the plug is withdrawn, the metal cap will be evacuated, and pressed down firmly onto the glass flange through atmospheric pressure; a greased ring of synthetic rubber set in a groove in the cap-flange ensures a good seal. The vacuum used during this outgassing process need not be particularly high, e.g. 10^{-4} mm Hg.

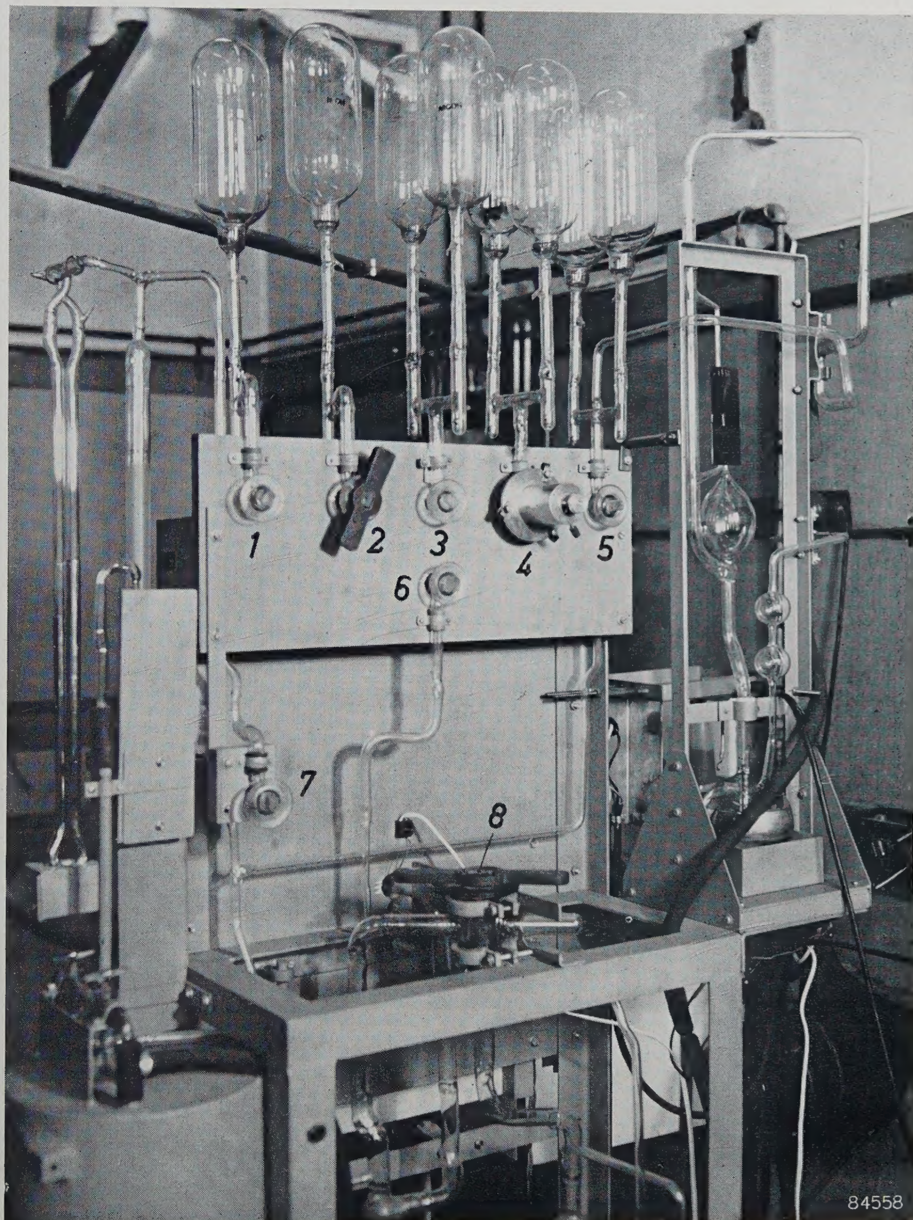

Fig. 3. A high-vacuum installation with nine taps as in fig. 2, eight of which (*1* - *8*) may be seen. A cap is attached to tap *4*, and operating keys to *2* and *8*.

The whole of the greased surface of the plug is now exposed directly to the vacuum. Due to this

fact, the time for the grease to lose nearly all its air is now a question of only about an hour.

When this time has been reached, the adjusting screw is screwed back in, so that the bellows expand and the plug is once more seated in the housing. Opening a small valve lets air into the cap, which may then be easily removed. The time now required to attain a vacuum of 10^{-6} mm Hg is very short.

On the first occasion that the tap is turned after one side of it has come into contact with the outer air, a further slight outgassing will occur; the pressure-increase due to this is appreciably less than that experienced with a normal tap after six months' use. The new tap is completely transparent after outgassing; this is a further indication that the grease in the tap contains no air.

It is also an important advantage that the new tap allows the use of types of grease having the best lubrication properties; these are less suitable for normal taps, since they are difficult to outgas.

As mentioned above, the plug is not provided with a handle for turning (fig. 1) but with a solid head (fig. 2). This is done primarily to keep the dimensions of the cap small. The plug is turned by using an operating key made of compressed cardboard, toughened fibre or a similar material. This is, indeed, also to be recommended for normal taps: glass handles are easily broken off. With a compact solid head and a key of tough material, this is virtually impossible.

Fig. 3 shows a high-vacuum installation, using a number of the new taps.

J. HORSELING.

ABSTRACTS OF RECENT SCIENTIFIC PUBLICATIONS OF N.V. PHILIPS' GLOEILAMPENFABRIEKEN

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2199: W. Ch. van Geel: Über die electrolytische Gleichrichtung (Contribution to Halbleiterprobleme I, edited by W. Schottky, Vieweg, Braunschweig 1954). (On the electrorectifier; in German).

The properties of the rectifier system aluminium — aluminium oxide — electrolyte are considered. The relation between current and voltage during the formation of the oxide layer agrees with theoretical expectations. Analysis of the behaviour of the impedance of the system as a function of frequency shows that the oxide layer is inhomogeneous in the direction of its thickness. The layer nearest the metal is well-conducting, whilst that nearest the electrolyte is poorly conducting. This asymmetry is closely related to the operation of the rectifier; without it, there would be no rectifying action. Rectification, as well as most of the other properties of the system, remains if the electrolyte is replaced by a semiconductor. An attempt is made to explain the rectification qualitatively.

2200: A. J. W. M. van Overbeek: Enige schakelingen met transistoren (T. Ned. Radiogenootschap **19**, 231-260, 1954, No. 5). (Some circuits using transistors; in Dutch).

After a short introduction to the physical principles of transistor action, the characteristics of junction transistors at low frequencies are given. The variation of the small signal parameters with operating conditions is described. At frequencies of 1-10 Mc/sec the equivalent circuit is already as complicated as the equivalent circuit of radio valves at frequencies a hundred times higher. Some low frequency circuits are given and the circuit diagram of a broadcast receiver is drawn. The bandwidth varies automatically with the signal strength so as to provide a narrower band for smaller signals. The variation of parameters with current can be described as a non-linear phenomenon. This gives information about modulation-distortion and cross-modulation of transistors compared with valves. In trigger circuits there is a natural limit to the operating speed, given by the frequency cut-off of the current amplification factor. A circuit containing a *pnp* and an *npn* transistor has properties resembling those of a gas discharge tube with adjustable ignition voltage, a short ignition time, a very low voltage drop and low discharge noise.

2201: S. Woldring and A. G. Th. Becking: Skin impedance and chronaximetry (Acta physiol. pharm. Neerl. **3**, 458-459, 1954, No. 3).

It is shown that the skin has an effect on the form of the intensity-duration curve of muscles and nerves even if the curve is obtained with a constant current stimulator.

2202: W. A. M. van Bergeijk and S. Woldring: Localization and range of the respiration centre of the carp (Acta physiol. pharm. Neerl. **3**, 460, 1954, No. 3).

With the aid of unipolar micro-electrodes, the medulla oblongata of the carp was systematically searched for potentials in the respiratory rhythm. It is established that two respiratory centres can be distinguished; their location is described.

2203: W. J. Oosterkamp: Nieuwe aanbevelingen voor radiologische eenheden en voor stralenbescherming (Ned. T. Geneesk. **98**, 2263-2264, 1954, No. 32). (New recommandations for radiological units and radiation protection; in Dutch).

Summary of new International recommendations on radiological units and protective measures adopted by the International Commissions for Radiological Units (I.C.R.U.) and for Radiological Protection (I.C.R.P.) in Copenhagen, July 1953.

2204: L. Schultink, H. Spier and A. van der Wagt: The abrasion of diamond dies (Appl. sci. Res. **A5**, 1-11, 1954, No. 1).

See Philips tech. Rev. **16**, 91-97, 1954/1955 (No. 3).

2205: J. Haantjes and K. Teer: Multiplex television transmission (Wireless Engineer **31**, 225-233 and 266-273, 1954).

Systems for the transmission of several television signals within a single television channel are described in this article; they are based on the use of signal components which cancel out in two successive pictures. A distinction is made between the sub-carrier and the dot-interlace systems. The typical characteristics of both systems are determined and, in particular, those characteristics which affect the separation of the signals at the receiver. Their application to colour television is considered and the conclusion is drawn that for this the sub-carrier system is to be preferred.

2206: A. Claassen and L. Bastings: Notes on the extraction of nickel-dimethylglyoxime by chloroform and on the photometric determination of nickel by the glyoxime method (Rec. Trav. chim. Pays Bas **73**, 783-788, 1954).

The extraction of nickeldimethylglyoxime by chloroform has been investigated as a function of pH. In pure nickel solutions extraction is complete in the pH range 4·7-10, in tartrate solutions in the range 4·8-12 and in citrate solutions in the range 7·2-12. Interferences by copper and cobalt are discussed. For the photometric determination of the extracted nickel as the oxidized nickeldimethylglyoxime complex, an improved procedure has been developed resulting in a colour system of great stability.

2207: W. J. Oosterkamp: Image intensifier tubes (Acta radiologica, suppl. **116**, 495-502, 1954).

See Philips tech. Rev. **17**, 71-77, 1955/1956.

2208: H. B. Haanstra: Quelques applications du microscope électronique aux Philips Gloeilampenfabrieken N.V. à Eindhoven (Rep. European Congr. Appl. Electron Microscopy, Ghent, 1954).

The author gives a series of examples of the application of the electron microscope in industrial scientific investigations, together with a brief description of preparation techniques. The examples cover the investigation of the shape and size of particles in powders and the appearance of surfaces.

2209: A. M. Kruithof: Some remarks on the measurement of furnace temperatures by thermocouples (Rep. Third Int. Congr. Glass, Venice 1953, publ. Rome 1954, pp. 529-539).

It is always difficult to judge the accuracy of given temperature-measuring instruments under given conditions. The author takes as an example an instrument long used in glass technology, viz. a suction pyrometer, in which the sensitive element is a thermocouple. When properly designed and set up, the suction pyrometer gives reliable results. Mounting, calibration and use are discussed. Careful attention must be paid to screening from radiation. The use of the instrument to investigate the recuperator of a glass furnace is described. The results obtained with the suction pyrometer are compared with those obtained with thermocouples without radiation shields.

R 258: F. K. du Pré: On the microwave Cotton-Mouton effect in ferroxcube (Philips Res. Rep. **10**, 1-10, 1955, No. 1).

A microwave beam traversing a ferrite will be split up into two beams with different velocities when a transverse magnetic field H is applied. This is the Cotton-Mouton effect. The ordinary beam has its magnetic field parallel to H, the extraordinary beam perpendicular to H. The beams will emerge with a phase difference. This phase difference is determined for Ferroxcube 4B as a function of the field. The frequency used is 9350 Mc/sec. By applica-

tion of Polder's theory to the simplified case of plane-wave transmission through a ferrite having a small damping loss, fair agreement with the experimental results is obtained.

R 259: W. L. Wanmaker, A. H. Hoekstra and M. G. A. Tak: The preparation of calcium halophosphate (Philips Res. Rep. **10**, 11-38, 1955, No. 1).

An investigation has been carried out on the reactions occurring in the preparation of calcium halophosphate, a phosphor used in fluorescent lamps. We started from a mixture of the following raw materials: $CaHPO_4$, $CaCO_3$, Sb_2O_3, CaF_2 and $SrCl_2$, this mixture being fired at different temperatures. In order to trace the behaviour of the activators three other mixtures were prepared, namely a mixture in which Sb_2O_3 has been replaced by Sb_2O_3, another one without Mn and a third without Sb. The transformations of the separate components and simple mixtures were studied by means of differential thermal analysis. During firing, the first reaction that occurs is the decomposition of the $MnCO_3$. At a higher temperature the $CaHPO_4$ is converted into $Ca_2P_2O_7$. This reaction is followed by the dissociation of the $CaCO_3$. The formation of the phosphor begins at a temperature of about 800 °C. The conversions of the activators are important for the quantum efficiency. A substantial part of the antimony volatilizes in the firing process, either as Sb_2O_3 or as $SbCl_3$. At 700 °C the majority of the antimony is converted into calcium antimonate. This compound can be transformed at higher temperatures, with production of the trivalent antimony required. During the firing in air part of the manganese oxidizes to Mn^{3+}, in consequence of which the fluorescent colour becomes relatively more blue. The calcium antimonates isolated by us appeared to have the composition $CaO.Sb_2O_5$. This substance fluoresces weakly and has a long afterglow.

R 260: F. A. Kröger, H. J. Vink and J. Volger: Temperature dependence of the Hall effect and the resistivity of CdS single crystals (Philips Res. Rep. **10**, 39-76, 1955, No. 1).

The D.C. dark-conductivity and the Hall effect have been measured with single crystals of CdS, pure and doped with Cl and Ga, from 25 to 700 °K. Peaks in the curves of the Hall constant as a function of the temperature indicate that two energy bands for conduction electrons are present. Analysis of the results shows that the data can best be interpreted by assuming that, apart from their mobility in the normal conduction band, the electrons can also move in a band situated at the donor energy level. In all cases electrons are found to be the current carriers. At room temperature the electron mobility in the normal conduction band, limited by thermal scattering, is found to be $\mu_c \approx 210$ cm²/V sec. The mobility in the donor band is found at low temperatures. It increases both with the concentration of donors and with the number of electrons in the donor band. Thermo-electric-power data at room temperature and the variations of the Hall constant with temperature can be explained by an effective electron-mass ratio $m^*/m_0 \approx 0.2$—0.3. The depth of donor levels below the conduction band in CdS-Cd and CdS-Cl is 0·01-0·02 eV at low donor concentrations, and decreases to zero at concentrations exceeding 10^{18} cm^{-3}. For insulating crystals, the conductivity and the Hall effect were measured upon illumination with the green mercury line (0.5 W/cm²). Irradiation with infrared in addition is found to cause a decrease in the concentration of free electrons. Capacity measurements with insulating crystals lead to a value of the static dielectric constant $\varepsilon_s = 11.6 \pm 1.5$. The temperature variation of the electron mobility as limited by lattice scattering above 200 °K can be quantitatively accounted for by optical and accoustical modes. With $m^*/m_0 = 0.2$-0.3, longitudinal optical modes give a characteristic temperature of $\Theta_0 = 250$-300 °K; for scattering at acoustical modes the electron mobility is given by the well-known formula $\mu_{ac} = aT^{-3/2}$, in which a is found to lie between 3×10^6 and 8×10^6 cm² degree$^{3/2}$/volt sec.